Thomas Lawley Jr

Trin: Coll: Dub.

Novr 1861.

MANUAL
OF
RAILWAY ENGINEERING
IN
IRELAND.

WITH APPENDICES,
INCLUDING
THE IRISH TRAMWAYS ACTS.

BY
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DUBLIN:
EDWARD PONSONBY, 116 GRAFTON STREET.
1861.

Transport.

PREFACE.

The object of the following pages is, to afford to young Engineers a guide to practical work, and to all a handy book for reference. With a view to the former, I have gone into details, and mentioned trifling points, to a degree which many will think useless, and almost as if done with the object of increasing the number of pages: but so far from that being my intention, I have done my best to bring the whole within as small a compass as possible. With a view to making it a book for reference, I have given abstracts of all which concerns the Engineer in the Standing Orders and Railways' Clauses Act, and have introduced many other things, such as gradient tables (page 28), etc.

When a young Engineer joins an office, he commences to learn his business, by keeping his eyes and ears open; and thus gradually picks up the knowledge of routine business, such as preparing parliamentary, or contract plans, etc.

My great object is, to give him a hand-book, which will explain to him the processes which he sees going on, and the reasons for them; and thus enable him to gain a

knowledge of them in much shorter time, and more thoroughly, than is generally the case.

With the one exception of the proof of the prismoidal formula, I have studiously avoided giving any mathematical investigations; as I assume that such subjects should be studied in books purposely written, and which are to be obtained easily, and of a far better kind than I could write.

I have similarly avoided the subject of instrumental adjustments, which the reader will find ably treated in one of Mr. Weale's series.

The practice of one office, I am aware, may differ from another; and I may perhaps appear to assume rather too freely that certain methods of doing things are the best. I do not wish to be so understood; I only give them as being, so far as I know, of the best kind, and I hope that, even where the practice differs from what I have written, this little book will not be without its use.

C. P. Cotton.

September, 1861.

CONTENTS.

PART I.

ON THE PREPARATION OF PARLIAMENTARY PLANS, AND THE EXECUTION OF OTHER WORK CONNECTED THEREWITH.

In the preparation of Parliamentary plans, the work which is required of the young engineer may be divided into the following operations:—

In the field,

Levelling,
Correcting plans,
Referencing;

And in the office,

Plotting section, and finishing up same,
Correcting plans and proofs, etc.,
Filling notices,
Preparing estimate.

Though each assistant engineer, when dispatched to the country, has special directions given to him about his work, still he should have a thorough knowledge of the requirements of standing orders: and therefore I give in this place extracts and explanations of so much of the standing orders of both houses of Parliament, as refers to the engineering part of the work necessary before obtaining a private act of parliament.

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STANDING ORDERS.

Standing orders are in two sets—one for the House of Commons, and the other for the House of Lords. I will mention those of the House of Commons first, and notice afterwards the differences between them and the orders of the House of Lords.

The first order that affects the engineer is No. 20; but as it comes last in order of time, I pass it over for the present.

ORDER No. 28 regulates the lodgment of plans and sections with the Clerk of the Peace. Two copies of the plan and section must be lodged with the Clerk of the Peace of each county through which the line of proposed railway passes, before the 30th day of November.

ORDER No. 30 requires that, if any tidal water be affected by the proposed works, a copy of the plans and sections be lodged with the Board of Admiralty, before the 30th day of November.

ORDER No. 31 requires that a published map, to a scale of not less than a quarter of an inch to a mile, with the general course of the proposed railway marked on it, be deposited at the office of the Clerk of the Peace of each county, before the 30th day of November.

The scale to which a published map must be made in England is one half inch to a mile, and this was also the order for Ireland, until the standing orders 1858–9, when it was altered.

ORDER No. 32 requires that a copy of the plans and sections, together with a published map, be lodged with the Board of Trade, before the 30th day of November.

ORDER No. 33 requires that a copy of the plans and sections, together with a published map, be lodged at the Pri-

vate Bill Office of the House of Commons, before the 30th day of November.

ORDER No. 34 requires that a copy of the plans and sections, of so much of the line as lies in any Union, be lodged with the Clerk of the Union before the 30th day of November.

The standing orders of the House of Lords require exactly the same lodgments as those above mentioned; but, instead of Order No. 33, the Standing Order No. 182, section 10, requires that a copy of the plans and sections, together with a published map, be lodged, before the 30th day of November, at the office of the Clerk of the Parliaments, an office corresponding to the Private Bill Office of the House of Commons.

The number of copies that an engineer must *necessarily* provide of the Parliamentary plans and sections is—

For the use of his own office		1
„	the solicitor	1
„	the promoters	1
„	the Parliamentary agent	1
For lodgment	at the office of the Clerk of the Peace	2
„	at the Private Bill office	1
„	at the office of the Clerk of the Parliaments	1
„	at the office of the Clerk of the Union	1
„	at the office of the Board of Trade	1
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This number is increased, when the proposed work lies in more counties than one, or in any way affects tidal waters.

The engineer must observe that he is required to lodge with *each* Clerk of the Peace, an *entire* set of plans and sections; but with each clerk of any union, only so much as affects *that* union; so that one set of plans may be cut up, and the pieces serve for lodgment at all the unions.

The number of "published maps" that are required is—

For the	Engineer's office	1
„	Private Bill office	1
„	Office of the Clerk of the Parliaments	1
„	Office of the Board of Trade	1
„	Promoters	1
„	Solicitors	1
„	Office of the Clerk of the Peace	1
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The number of these maps is likewise increased, if the proposed work be situated in more counties than one.

No published map is required for an union, nor for the Board of Admiralty.

ORDER No. 43 requires that the general plan be on a scale of not less than four inches to a mile, and that if the scale is less than one inch to four hundred feet, an enlarged plan on a scale of four hundred or more feet to one inch be given of every building, yard, court-yard, or land within the curtilage of any building, or ground cultivated as a garden, that is situated within the "limits of deviation" as marked on the plan.

In Ireland it is usual to make the large ordnance map the basis of operations; it is on a scale of six inches to one mile, and, thus, within the prescribed limit of scale.

ORDER No. 45 requires that the distances from one of the termini be marked in miles and furlongs; and that if any curve be proposed of a radius of, or less than *one mile* in length, the length of the radius shall be described in *furlongs and chains*. Also, that if tunnelling be intended, the portion of the centre

line which is proposed to be in tunnelling, shall be shown by a dotted line.

The chains referred to here, and in Acts of Parliament, are chains of 66 feet.

The engineer is at liberty, afterwards, to substitute tunnelling for open cuttings; but he must make, and defend, his parliamentary estimate on his parliamentary plans and sections, irrespective of any alterations.

ORDER No. 46 requires that any diversion of a turnpike or public carriage-road, navigable river, canal, or railway, shall be shown on the plan, and any proposed alteration in the width of the same noted.

This only requires that any alteration for which power under the special act is necessary shall be shown: the fact of any alteration not being shown, does not preclude the engineer from availing himself of the provisions of the Railway Clauses Act, 8th Vic., c. 20.

ORDER No. 48 requires that the horizontal scale of the section be the *same* as that used for the general plan, and that the vertical scale be not less than one inch to one hundred feet. Also, that a datum line be shown and described.

The datum line represents an imaginary level, by a certain vertical height above which, every point that is required to be fixed is determined. The datum line must be continuous throughout the section, and its position defined with reference to some *fixed* point *near* one of the termini.

Key-stones and parapet stones of bridges, and cills of doors of public buildings, are used as points of reference for a datum line; but not only must the point of reference be fixed, but the description of it must be minute and unmistakeable.

The level of rails of a running railway, at a fixed point, has been held to be insufficiently *fixed* for a point of reference.

If the proposed work be a deviation from previously authorized plans, the datum level should be referred both to the point of reference of datum of original plans, and *also* to a fixed point near one end of the proposed deviation.

The distance of the point of reference of the datum should not be more than about one thousand feet from one terminus, and the nearer it is the better.

ORDER No. 50 requires that the line representing the railway shall be the upper surface of rails.

ORDER No. 51 requires that the distances along the datum line be marked in miles and furlongs, to *correspond* with the general plan; that the height from datum shall be figured at each change of gradient, and also the rate of inclination of each such gradient marked in figures.

ORDER No. 52 requires that the vertical height from the rails to the surface of ground shall be shown wherever the railway crosses any public carriage road, canal, or railway: also, that if the railway be proposed to be carried over any public carriage road, navigable river, canal, or railway, the height and span of *every* arch of all such bridges shall be marked in figures on the section; and that if any public carriage road be proposed to be crossed on the *level*, it shall be stated with or without alteration, as may be intended.

ORDER No. 53 requires that, if any alteration be intended in the water-level of any canal, or in the level or inclination of any turnpike road, public carriage road, or railway, the same shall be stated on the section, and each such alteration shall be numbered, and cross sections, with corresponding numbers, shown.

The cross sections, above referred to, must be on a horizontal scale of not less than 330 feet to one inch, and a vertical scale of not less than 40 feet to one inch, showing the present surface of road, and intended alteration, and the greatest inclination of each, not only *in figures* along those surfaces, but also *in writing*.

If a road, canal, or railway, be proposed to be crossed by a *bridge*, without an alteration in its level, no cross section need be shown; but if a *level* crossing be intended, a cross section must be shown in any case.

Cross sections must extend to a distance of at least two hundred yards on each side of the centre line, as it is shown on the general plan.

ORDER No. 54 requires that the height of any cutting or embankment, and of each portion of a cutting divided by a tunnel, and of each portion of an embankment divided by a viaduct, be shown *in figures*, if same exceed *five feet*.

ORDER No. 55 requires that tunnelling, or a viaduct, if intended, be shown on the section.

It is usual to describe tunnels and viaducts in writing, as well as to mark their position on the section.

ORDER No. 20 requires that a notice be served on every person interested in any lands, or houses, affected by the proposed works, before the 15th day of December.

These notices must contain particulars about the work, which must be furnished by the engineer, as will be described further on.

The requirements of these standing orders will be further noticed throughout the description of parliamentary, field, and office work.

LEVELLING.

In Parliamentary work time is always of great value, and accordingly the line of any railway, if of any great extent, is divided into sections of six or eight miles in length, to each of which is appointed an assistant engineer to make the section, and another to correct the plans and references.

Of course it is according to the time available that the engineer-in-chief determines on the length of such sections, and the advisability of employing one, or two, assistants on each section.

The assistant engineer who is charged with the execution of the levelling, having provided himself with a set of Ordnance maps, marks, with the minutest accuracy, the centre line as laid down by the engineer-in-chief, and having received his instructions, starts for the country.

Every morning, before commencing work, he should examine his level, and see whether it is in adjustment or not, as not only may very valuable time be saved by this precaution, but he may be saved the annoyance of having the accuracy of his work called in question, in case he should be produced as a witness afterwards.

The adjustments of the level I have nothing here to say to; they will be found in many books on that particular subject. I will only say that on account of the *speed* and *certainty*, both of *detecting* and *adjusting* any errors, I myself much prefer the Y level for this work; though I am bound to state that the dumpy is in more general repute among the best practitioners. The testing and adjusting of a dumpy, if out, occupy much time, and never to my mind give the thorough confidence that an engineer should have in a level, and which he can have in a Y level.

At starting, and about every mile along his portion of the

line, the engineer should fix on a good benchmark, to serve in checking his own work, and also for reference for any engineer appointed to re-level the same ground: with a view to the latter proceeding, each benchmark should be unmistakeably described in the level book.

Should the division the engineer is engaged on be the terminal one nearest the datum point of reference, he should start from that point.

The engineer then proceeds to level along the line, as shown by the Ordnance map. He must determine the position of each sight with reference to fixed points on the map, such as intersections of fences, houses, limekilns, roads, etc. As a *general* rule he should take a sight near each fence, and intermediates wherever the contour of the ground varies from a straight line by two feet.

Where the Ordnance map is well filled in, and the country ordinarily smooth, ranging rods are not required; but in the cases of rough side-long ground, or where the filling in of the map is deficient, they are indispensable.

The best scale with which to measure distances on an Ordnance map is one cut off that particular map; but for all purposes of field work, a scale such as is made by Elliott, called a "shrunk Ordnance" scale, is sufficiently accurate. These scales are graduated from an average of Irish Ordnance sheets, and are about 5.925 inches to one mile. A scale graduated to 80 to an inch is the most convenient of ordinary scales for using with the six-inch Ordnance map, each division representing 11 feet.

The engineer must not expect to find all the fences correct on the Ordnance map, and as he is always sent out to level before the sheets are corrected, he must be careful not to be led astray by new fences, or the omission or removal of old ones.

Some of the Ordnance maps, particularly in the north of Ireland, are very deficient in the filling in; but this is gradually being remedied. He should note in his field book everything that may occur to him as likely to be of use, such as the nature of the ground, as moor, red bog, clay, gravel, or rock, and the *kind* of rock; the size of streams, and rivers, the size of existing bridges and culverts, the height of floods, etc., etc.

As in parliamentary levelling, the centre line is not chained, the engineer must give in the column headed "distance" in his field book, some means of referring to the position of each observation.

This is usually effected by marking the points on the plan with either letters or figures, and entering the same opposite the respective sights in the field book. Where sights are taken at points intermediate, or badly defined on the plan, their position must be marked by entering the measured distance from the nearest well determined point.

The engineer will do well to mark in these numbers or figures on his plan, in carmine or lake, in the evening. This does not spoil the map for other purposes, as the carmine can be totally removed by the application of a solution of chloride of lime.

The column in the field book, headed "reduced level", should not be filled until the datum level is fixed; yet the engineer should reduce his book before commencing his check-levelling. For this purpose I recommend him to rule off a column on the margin of the right-hand page, in which to reduce his levels to an arbitrary datum for comparison with the check levels. In this column no reduced levels need be entered for intermediate sights, nor for any sights in a page in which no sight on a *benchmark* occurs. Without causing the least delay, the engineer will find that he can fill up this column in the field as he goes on.

If the engineer has his book so reduced, he can instantly, on getting the datum from the man before him, hand it on to the next assistant.

Having completed the levelling of the centre line, the engineer returns over his benchmarks, checking the levels of *each*. The errors in checking should not be more than one-tenth of a foot in any one mile; if a greater error occurs, the levelling between those benchmarks should be repeated.

He next proceeds to make the cross sections, *i. e.*, sections along roads which cross the centre line of railway, and sections of diversions of roads, canals, or railways.

Except he receives special instructions to the contrary, he should make a section of *every* such public road that he meets for 200 yards on each side of the centre line, as he cannot as this stage tell whether a level crossing be not proposed at that road, in which case a section is always necessary, or whether the gradients will admit of its being passed over, or under, the railway with "level unaltered".

Standing orders do not require sections of diversions of roads, even when proposed to be altered; nevertheless, they are generally given, if any alteration in gradients be contemplated.

The distances, in making cross sections, should always be measured with a chain or tape.

Where there is a branching road within 200 yards of the centre line, the section should be made along each such branch, as shown by the cross section, No. 2, Plate 1.

CORRECTING PLANS IN THE FIELD.

In Ireland the six-inch Ordnance map is generally taken as the basis of the plan, and it is the duty of one assistant, as

mentioned before, to correct the Ordnance map in the field, and finish it up, and prepare it for the lithographer, in the office.

The assistant appointed to correct the plans first marks on his Ordnance sheets the centre line very exactly, and also the limits of deviation, as directed by the engineer-in-chief, and then proceeds to the country.

He then walks over the ground, examining every field, and house, any part of which is within limits, and corrects the Ordnance sheet by marking in all new fences, and crossing out all fences which have been thrown down since the date of the map he is using.

If the Ordnance map is deficient, he must survey in whatever details are wanting.

Fences that have disappeared should be *crossed out* on the map, and not *erased;* and new fences should be inserted with *red ink*, and not with Indian ink. This method of proceeding is important, as it insures no *correction* being overlooked, when the maps for the lithographer come to be prepared.

He must also prepare enlarged plans of any *house* or *garden*, any part of which is inside the limits of deviation.

These enlarged plans are usually prepared on a scale of 300 or 330 feet to one inch; but sometimes, as in passing through a town, where the houses are numerous, a much larger scale is used with advantage.

If the houses are marked on the Ordnance map, he may enlarge *it*, and correct the enlargement in the field; but if they are not marked he must survey them regularly.

Enlarged plans should be given of any limekiln, or building of any kind, even of ruins of which only part of the walls are standing.

The limits of deviation are usually marked at a distance of 300 feet on each side of the centre line; but are contracted in

passing through towns, and, occasionally, through valuable land, or ground that must be avoided in order to prevent opposition.

The limits are often put at *more* than 300 feet; but then they are not strictly limits of *deviation*, as, by 8th Vic. c. 20, the centre line can nowhere be deviated more than 300 feet in open country, and 30 feet in ground continuously built upon; but by so extending the limits compulsory power of purchase may be obtained.

CORRECTING PLANS IN THE OFFICE.

Having returned to the office with his field plans corrected, the assistant sets to work, and prepares a correct plan for the lithographer to work from.

He first marks on the centre line and limits of deviation, as directed, and also lines showing how much of the plan is to be lithographed; for though standing orders require nothing to be shown outside limits, it is usual to show an inch wide or so on each side.

Perhaps the best plan is to cut out so much of the map as he wishes to have lithographed, and mount it on a separate sheet of paper, in the position he wishes it to occupy when lithographed. Errors in the part shown outside limits of deviation are of no consequence.

He now carefully *erases* any fences or houses which he has crossed out on his field map, and inserts in black all new fences and houses. The object of having made his corrections in red is now evident.

He now plots each enlarged plan, somewhere near its position on the general plan, indicating its position by writing, or by a direction line; both methods are shown on Plate 1; the former above and the latter below the general plan.

On these enlarged plans the centre line and limit of deviation on that side of the centre line on which the house or garden is situated, must be shown.

If the assistant has cut out the portion of the Ordnance sheet which is to be lithographed, he must carefully make out, and print on the slip, the name of each townland, parish, and county; and at every parish or county boundary describe same in writing.

Townland boundaries need not be so described in writing.

He must also make out for the solicitor a list of such townlands, parishes, and counties, and take the greatest care to make such list perfect, as an omission in it would be a fatal objection to the bill.

He next proceeds to mark each enclosure, house, river, and road, with a number of its own.

These numbers need not be consecutive, and may be repeated, by townlands, or by parishes. If by townlands, which is the most convenient, no number must be repeated in the *same* townland except with an affix attached, as 17a, 17b. If a number has been put in by mistake it may be erased.

In the case where a townland boundary runs along the *middle* of a road or river, the road or river must have a distinct number in each townland.

If *possible*, every number should be shown on the general plan; but sometimes the divisions are so minute that they cannot be distinctly inserted, and as this always occurs in a place where an enlarged plan is required, a note is usually put on the plans, to the effect that "when the divisions are too minute to allow of the numbers being inserted on the general plan, they are shown on the enlarged plans".

The words "limit of deviation" should be written on *each* limit at *each* end of the sheet, and also on the limit, or limits, as shown on each enlarged plan.

The boundaries of townlands, parishes, and counties should be given in the same character as that which is used on the Ordnance map.

The miles and furlongs should be marked and figured.

If the radius of any curve be of, or less than, one mile in length, its length in furlongs and chains should be written either along the curve or at right angles to it.

If any road, railway, river, or canal be proposed to be diverted, the general course of such diversion should be shown by dotted lines, and the words "proposed deviation of road", or river, written along them.

If tunnelling be proposed, the centre line for that length must be dotted.

The plan and section may be arranged in two different ways; either eight miles of plan on a sheet, or four miles of plan, and the corresponding four miles of section, are put on the same sheet.

Scales *need* not be given at all; but they always are, either on every sheet, or on the first page only, and sometimes on the title-page only.

THE SECTION.

When the engineer, who has made the section, has reduced his book to the proper datum, he plots his section in the office. In doing this he must take his distances from the Ordnance which he has been using in the field, but must also make the distances correspond with those on the copy which is prepared for the lithographer.

Ordnance maps differ greatly in shrinkage, and it is quite necessary that the position of the roads, etc., on the section, as referred to the miles and furlongs, as well as the lengths of

the miles and furlongs themselves, should *exactly* agree with the plan *when lithographed.*

He next puts on the gradient lines, under the directions of the engineer-in-chief.

The object being, of course, to make the estimate of the line as light as possible, the gradients should be laid so as to make the quantities in the cuttings as nearly as possible, equal to the quantities of the neighbouring embankments.

While laying down the gradients the engineer must look to everything that may affect the cost of the work, such as heights of floods, sections of roads crossed, and the practicability of under or over bridges.

He must also keep in mind the positions of intended stations, and there provide for horizontal or easy gradients, for 700 or 800 feet at least.

He must remember that the gradient line represents the top surface of rails, and consequently that an embankment will appear considerably larger than a cutting which contains the same number of cubic yards of material.

The introduction of tunnels, and their lengths, should be determined on with a view to the great desideratum of a minimum estimate. The simplest case is where a tunnel is substituted, instead of a cutting *which would be run to spoil.*

Let h be the height of the cutting in feet,
b the base in feet,
r the ratio of slopes,
p the price per cube yard of excavation,
P the price per yard run of the tunnel;

and it follows that where the amounts are equal,

$$h = \sqrt{\frac{9 \times P}{p \times r} + \frac{b^2}{4r^2}} - \frac{b}{2r}$$

and that in any deeper cutting the tunnel is cheaper, and

vice versa. If, however, the cutting be required for an embankment, the engineer must not forget to charge against the tunnel the cost of side-cutting necessary to replace the cutting.

Having put on the gradients, he must see that standing orders are complied with in the following particulars:—

Heights of cuttings and embankments must be marked, if exceeding five feet.

The inclination of each gradient, and the gradient heights must be given.

Public roads, etc., must be marked, and the manner in which the railway will affect them, and also the height of embankment or cutting at *every* road.

Under-bridges must be described as to span and height.

A description, clear and unmistakeable, must be given of the datum level.

The miles and furlongs must be marked and numbered.

Viaducts and tunnels must be marked, if proposed.

Cross sections of every road *altered* for the purpose of being passed over or under the railway, must be given.

Cross sections of all proposed level crossings, whether the road be proposed to be altered or unaltered, must be shown.

The description used in the case of roads, affected in different ways, is shown in Plate I.

The amount of alteration in the level of a road will depend on the kind of bridge that the engineer proposes to himself for each case.

If the bridge be an over one, the height, supposing, as is

usually the case, that it is to be constructed for a double line of rails, from the top surface of rails to highest point of road will be, for a stone bridge, 19 feet 6 inches, and for an iron bridge 16 feet 9 inches.

These are the general heights, but they will vary with the height of the chimney of the engines proposed to be used.

If the bridge be an under one, the height from the road surface to top surface of rails will be—

For a public road,	if the bridge be stone,	22 ft.;	if iron,	17 ft. 8 in.
For a turnpike road,	,,	23 ft.;	,,	19 ft. 8 in.
For a private road,	,,	22 ft.;	,,	16 ft.

If, however, the engineer thinks well, he may not give so much headway as these figures would allow, which are made out on the supposition of the headways being those laid down in the Railways' Clauses Act, 8th and 9th Vic., c. 20, and which are generally used on parliamentary plans.

The inclinations shown on the cross sections, except there be special reasons to the contrary, should be at least equal to the inclinations laid down by the Railways' Clauses Act, namely—

For a turnpike road, 1 in 30.
For a public road, 1 in 20.

In Ireland every mail-coach road is considered as a turnpike road.

If engineering difficulties prevent these heights and inclinations being given, the fact must be mentioned in the *bill* as well as shown by the cross sections.

LITHOGRAPHING.

The plan and section having been finished, tracings are most carefully made and furnished to the lithographer, who in a few days sends to the engineer a *first* proof. The litho-

grapher will undertake the tracings himself; but it is the more satisfactory plan to have them made in the engineer's office, if convenient.

The engineer now compares the proof with the original, and marks all corrections prominently in red ink, and returns it to the lithographer, who afterwards furnishes a *second proof.* Having corrected the second proof, the engineer should attend himself in the lithographer's drawing office, and *see* these second corrections put on the stone. He will thus save, what is generally most important at this period, *time*, as he can examine, and correct the next proof as soon as it is pulled; and if it be right, give the order to print at once, saving the delay of interchanging proofs, and of shifting the stone.

Some one from the engineer's office should attend, and watch the printing, examining the sheets occasionally; this is necessary to avoid two errors that corrected stones are liable to, viz.:—lines that have been erased will sometimes reäppear *during* the printing, and lines that have been inserted will sometimes not come up. In either of these cases he should get the lithographer at once to retouch the stone. If this be not attended to, one great object of lithographing is lost, that is, the certainty of a perfect identity in all the copies.

When the copies are printed, they should be *again* examined with the original, and all corrections marked prominently in red on one copy, to be called the "office copy", and with which every copy before issue should be carefully compared.

Even though the greatest care has been used all through, there will be found some mistakes at the end.

REFERENCING.

In accordance with standing orders, a book of reference must be prepared by the solicitor, and lodged with the plans on or before the 30th November.

This book must contain each number that is shown on the plan, with a description of the property, and of all persons interested in any way in it.

It is the solicitor's business to make out this book, and for this purpose he despatches an assistant to the country to make inquiries.

This assistant, almost always, requires an engineer to accompany him to point out the lands, and to see that the numbers and descriptions in the book of reference correspond with the same on the plans.

If the lithographed sheets are ready, of course the engineer takes a copy of them with him, and besides his special business as a guide to the solicitor, keeps an anxious eye out for mistakes in the plan.

Should time press, and the engineer be unable to get the lithographed sheets, or even corrected duplicate proofs, he must put the numbers and limits on Ordnance sheets exactly as they are on the copy furnished to the lithographer.

During the referencing, numbers may be struck out or inserted, if required. If new numbers are inserted, it will always be more convenient if they are formed by different affixes put to numbers belonging to the *same* owners. All such alterations should be *prominently* marked.

When the fair copy of the book of reference is made out, and the plans ready, they should be again compared, and both numbers and descriptions checked.

The plans being now ready, are labelled, and handed over to the solicitor for lodgment, *and a receipt obtained from him.*

NOTICES.

On or before the 15th day of December the solicitor has to serve each person in any way interested in any property mentioned in the book of reference with a notice, according to a form given in the standing orders.

These notices must contain information as to the situation of the proposed works, as regards the property represented by each number.

The solicitor sends a copy of the book of reference to the engineer, who makes opposite each number a note that—

1. *No* part of the land or house is within 33 feet of the centre line of the proposed works, or
2. That some part of the land or house *is* within 33 feet, but *no part intersected*, or
3. That the property is intersected by the centre line, and the way it is affected by the works.

This is usually done by writing.

2. "Out".
1. "Within".
3. "— ft. emb." or "— ft. cutting", as the case may be, and if the number be a road, railway, or canal, the alteration in level proposed should be stated.

ESTIMATE.

The engineer next proceeds with the estimate, which must be lodged before the 31st December.

From the section he takes out the quantities of the embankments and cuttings. The notes of the engineer who prepared

the sections, with borings if thought necessary, enable him to separate the rock from the clay cuttings.

I refer the reader for details of the method of taking out quantities to the second part of this work.

The estimate is there more minutely described than it would be in this place, greater particularity being required in contract work.

The engineer must here, as elsewhere, remember that where *less particularity* is said to be required, it does not mean that *carelessness* will be excused; but that *time* must not be wasted on minute details, which are out of place.

Where vigorous opposition is expected, of course more care is taken with the estimate.

In Parliamentary work it is not of such importance, as it would appear at first sight, to have ascertained the amount of rock in the cuttings. This is owing to the fact, that for moderate heights the cost of a clay-cutting and the cost of a rock-cutting, at present prices, differ but very slightly; for instance, a cutting of 18 feet deep in clay, with a base of 18 feet, and slopes of $1\frac{1}{2}$ to 1, contains 90 cubic yards to the yard run; which, at 9d. per yard, will cost £3 7s. 6d. per yard run, while the same cutting in limestone, with a base of 15 feet, and slopes of $\frac{1}{4}$ to 1, contains 39 cubic yards, which at 2s. per yard, will cost £3 9s. per yard run.

It is of more importance when the cutting is balanced against an embankment, so that if it turns out more rock than expected, side-cutting must be provided, and charged for in the estimate.

Soiling, earthwork, side-cutting, road approaches, ballast, and laying way, are taken out as for contract work.

Culverts may be either taken in detail, or at so much per mile, as suggested by the experience of the engineer-in-chief.

Bridges may be taken from former contracts, or from specially prepared drawings.

Permanent way is estimated at a price per mile, and a liberal allowance must be made here, as well as in estimating for the laying way and ballast, for sidings, etc.

The items which make up the cost of permanent way are:

Iron rails	at —— per ton.
Chairs	at —— per ton (if any).
Fastenings	at —— per ton.
Fishplates	at —— per ton (if any).
Royalty	at —— per ton (if any).
Sleepers	at —— per cubic foot or per ton.

Cutting, grooving, and boring sleepers at —— per sleeper.

Freight of Iron	at —— per ton.
Insurance of Iron	at —— per ton.

The ton of timber is 40 cubic feet.

Some engineers prefer including the laying and ballast under the head "Permanent Way".

Land is valued by a professional valuator, and the cost introduced by the engineer. In case of opposition, the valuator must prove the value of the land before the committee.

Accommodation works are estimated per mile, according to the experience of the engineer-in-chief, or according to works which he thinks necessary.

Stations may be estimated from existing examples.

When the total is brought out, 10 per cent. at the least, should be added for contingencies and law and engineering expenses.

The estimate is then in this form:—

Quantity.		Price.	£	s.	d.
	Cubic yards excavation in clay,				
	„ excavation in rock,				
	„ side cutting,				

Quantity.		Price.	£	s.	d.
	Cubic yards, road metalling,				
	„ embanked road approaches formed from railway cuttings,				
	„ do. formed from side cutting,				
	„ excavation of road approaches,				
	„ diversions of rivers,				
	„ ballast and boxing,				
	Super yards, trimming, soiling, and sowing slopes,				
	Lineal yards, laying permanent way,				
	„ fencing,				
	Miles, culverts,				
	bridges,				
	Miles, land,				
	accommodation works,				
	„ permanent way,				
	stations,				
	Total, £				
	10 per cent. for contingencies, law and engineering, . . .				
	£				

If the country be a very easy one, 10 per cent. is not sufficient to cover law and engineering expenses, as well as con-

tingencies; the proper per-centage is to be settled by the engineer-in-chief.

The estimate is lodged in a very simple form:—

——— Railway.

I estimate the expense of the above undertaking at —— pounds sterling.

——— Engineer.

Should the railway pass through a thickly-inhabited place, so that in any one parish thirty houses within limits belong to the labouring classes, a statement to that effect must be lodged before the Bill enters the House of Lords; the engineer should make himself acquainted with all such cases, as he has to make an affidavit of there being, or not being, thirty houses affected as above.

The engineer-in-chief is obliged to depose to the plans, etc., being in compliance with standing orders.

In the case of an unopposed line, this is done by affidavit sworn anywhere; but in case of opposition, it must be sworn to before the examiners in London.

END OF PART I.

PART II.

ON THE PREPARATION OF DETAILED PLANS AND SECTIONS, WITH BRIDGE DESIGNS, PREVIOUS TO THE LETTING OF THE CONTRACT.

Soon after the Bill has become an Act, the engineer-in-chief receives instructions from the company to proceed with the contract surveys.

The engineer-in-chief now reëxamines the plans, profiting by all the knowledge gained during the preparation of the Parliamentary plans, and makes what alterations may seem advisable to him, keeping, of course, within the limits prescribed by the special Act, and by the general Railways' Clauses Act, 8th Vic., cap. 20.

RAILWAYS' CLAUSES ACT.

This Act now takes the place of "Standing Orders", as (coupled with the private Act, authorising the project) the guide of the engineer in getting up his work, so as to avoid all technical objections and opposition.

As regards the survey, and general engineering of the work, the Railways' Clauses Act affects the engineer as follows:—

CLAUSE No. 7 enables the company, in case of any omission or mistake with regard to any lands, to have same remedied by the process described. This would apply to the case where reference is entirely

omitted, and where, without this clause, no compulsory power of purchase could be exercised, and, which concerns the engineer, no compulsory entrance effected.

CLAUSE No. 11 prescribes the limits within which the level of rails at any point may be altered from the Parliamentary height, *without* the consent of those interested. In open country, the variation may amount to five feet either higher or lower; and in land continuously built upon, two feet.

With the consent in writing of all interested, the variation is not limited by this clause, though it may be indirectly by clause 14.

It must be particularly noticed, that this variation is not to be estimated as one in the height of embankment, or depth of cutting, on or in any field, but as a variation from the height of the rails *at that point over the datum line* referred to in the Parliamentary plans.

If the effect of the alterations is to construct the line at any point with a lower embankment, or viaduct, the variations may exceed the five feet, or two feet, as the case may be; the requisite headway for bridges over roads, etc., being left.

This does not apply to cuttings. Greater variations than five feet and two feet respectively cannot be made, because a cutting is thereby lessened in depth; the reason probably being to prevent the facility for making accommodation bridges being affected.

When the consent, as above, has been obtained, further steps are necessary to legalize the variation, as pointed out in—

CLAUSE No. 12, which requires that public notice of such alteration be given by advertisement; and, if any objections be made, the question is to be decided by the Board of Trade.

CLAUSE No. 13 requires that tunnels and viaducts, when marked on the Parliamentary section, shall be made, and made of the *length* there shown, excepting, that in the case of a tunnel it may be dispensed with, with concurrence of all interested.

CLAUSE No. 14 authorizes the substitution of tunnels for cuttings, and viaducts for embankments, a certificate having been previously obtained from the Board of Trade, that such alteration is "consistent with the public safety, and not prejudicial to the public interest". This clause also limits the alteration of gradients and radii of curves. Gradients of, or steeper than 1 in 100, may be altered for the worse not more than three feet per mile, and gradients flatter than 1 in 100, ten feet per mile. The radius of any curve greater than half a mile, may be lessened to one half-mile, but no sharper curve can be altered for the worse.

The limits to which the engineer may go in altering gradients are shown in the following table:—

Parl. Gradient.	May be changed to.	Parl. Gradient.	May be changed to.	Parl. Gradient.	May be changed to.
1 in 50	1 in 48.6	1 in 95	1 in 90.1	1 in 400	1 in 227.6
1 in 55	1 in 53.3	1 in 100	1 in 94.6	1 in 500	1 in 256.8
1 in 60	1 in 58	1 in 110	1 in 91	1 in 600	1 in 280.9
1 in 65	1 in 62.7	1 in 120	1 in 97.7	1 in 700	1 in 300.9
1 in 70	1 in 67.3	1 in 130	1 in 104.3	1 in 800	1 in 318.1
1 in 75	1 in 71.8	1 in 140	1 in 110.7	1 in 900	1 in 332.8
1 in 80	1 in 76.5	1 in 150	1 in 116.9	1 in 1000	1 in 345.5
1 in 85	1 in 81.1	1 in 200	1 in 145.1	Horizontal	1 in 528.
1 in 90	1 in 85.6	1 in 300	1 in 191.3		

A curious point may be here noticed, that if the gradient on the Parliamentary plans be 1 in 100, it can only be increased to 1 in 94.5; yet if the gradient be 1 in 101, it can

be increased to 1 in 84.8. Hence it is advisable to introduce gradients of 1 in 101, in preference to 1 in 100, in Parliamentary sections. In curves or gradients any deviations whatever may be made, if the sanction of the Board of Trade be obtained for them.

CLAUSE No. 15 prescribes that the railway shall not deviate from the line marked on the Parliamentary plans to a greater extent on either side than—

(*a*) in open country, 100 yards.

(*b*) in land continuously built upon, 10 yards, and

(*c*) nowhere beyond the "limit of deviation" as marked on the Parliamentary plans.

In fact, the engineer is bound by his "limit of deviation", when within the limits given by (*a*) and (*b*). Provided that the adjoining lands into which the *works* would extend outside the limits, either as in (*a*) and (*b*), or in (*c*), have been referenced, the *centre line* may be deviated to the very *line* of limit.

CLAUSE No. 16, among other things, authorises the company to divert any unnavigable stream, or any road within the referenced lands, for the more easy passing same over, by the side of, or under the railway.

CLAUSE No. 17 requires the sanction of the Board of Admiralty to any structure affecting tidal waters.

CLAUSES Nos. 18 to 23 describe the necessary works and method of procedure, when the railway crosses water-pipes or gas-pipes.

CLAUSE No. 24 protects the engineer from having his work interfered with, by a penalty of £5 for every such offence.

It is of course to be presumed that in all such cases the engineer has a legal right to be on the ground, which he has

when it is bought by the company, or, *as affects the contract survey*, when he has given the requisite notice of his intention to enter, as prescribed by 8 Vic., cap. 18, sec. 84.

CLAUSE No. 25 requires the engineer, before proceeding with the work, to lodge with the Drainage Commissioners a copy of the plans and sections, and to receive from them a certified schedule of culverts and bridges necessary for any water flowing *across* the line of railway.

Drains under approaches to bridges, which are parallel or nearly so to the line of railway, do not come under this head, and are not noticed.

This lodgment with the Drainage Commissioners is the only case in which the engineer is required to lodge the contract *sections*.

The next clauses affecting the engineering of the line are very important; they regulate the manner in which all crossings of roads and railways shall be constructed.

CLAUSE No. 46 provides that no public carriage road shall be crossed on the level, except specially authorized by the company's act.

The engineer must be cautious, when laying down his contract gradients, and making out his estimate, not to put down a road crossing as a "level crossing", merely because it appears on the Parliamentary plans that the road is "to be raised (or lowered) ——feet and crossed on the level". Roads are often, at first, proposed to be so crossed, but on the objection of the officer of the Board of Trade, many such crossings may be struck out of the bill. The engineer must go entirely by the private act, and must make arrangements for every *public* road, not specially mentioned in it as *a level crossing*, to be carried over, or under, the railway, subject to the rules of the clauses 49, 50, 51, 52, at the same time

allowing for any infraction of these clauses that may be legalized by the special act and plans; *e.g.* the Railways' Clauses Act requires an inclination of 1 in 20 for every public carriage road approach; but if the special act sanctions an approach of 1 in 15, he may construct it accordingly.

This clause enables the company, with consent of two justices duly obtained, to make a level crossing on any highway not a *public* road.

CLAUSE No. 47 relates to level crossing gates.

This will be treated of when I come to the regulations and requirements of the Board of Trade, previous to the opening of a line for public traffic.

CLAUSES Nos. 49, 50, 51, and 52 require—

Firstly, that in the case of a mail road,

(*a*) The width between the abutments, if the road be passed *under* the railway, and between the parapets, if the road be passed *over* the railway, shall in *no* case be less than 30 feet, and this width shall be increased up to a *limit* of 35 feet, if the road be wider than 30 feet.

(*b*) The arch shall be such as to admit of a rectangular box, 16 feet high and 12 feet wide, passing through it.

(*c*) The height of the springing of the arch over the ground shall be 12 feet at least.

(*d*) The inclination of the approaches to the bridge shall not be worse than 1 in 30, or than the mesne inclination of the existing road, if such be worse than 1 in 30.

(*e*) The height of the parapets, if the bridge be over the railway, shall not be less than 4 feet, and the height of the fences on the approaches shall not be less than 3 feet.

Secondly, that in the case of a public road,

(*a*) The width between the abutments, if the road be passed *under* the railway, or between the parapets if the road be passed *over* the railway, shall in no case be less than 20 feet, and this width shall be increased up to a limit of 25 feet, if the road be wider than 20 feet.

(*b*) The arch shall be such as to admit of a rectangular box, 15 feet high and 10 feet wide, passing through it.

(*c*) The height of the springing of the arch over the ground, shall be 12 feet at least.

(*d*) The inclination of the approaches shall not be worse than 1 in 20, or than the mesne inclination of the road, if such be worse than 1 in 20.

(*e*) The parapets and fences shall be as required above for mail roads.

Thirdly, in case of a private road,

(*a*) The width between the abutments, if the road be passed *under* the railway, or between the parapets, if the road be passed *over* the railway, shall be not less than 12 feet, no variation with the width of the road being allowed as in other cases.

(*b*) The arch must be such as to allow of a rectangular box, 14 feet high and 9 feet wide, passing through it.

(*c*) The height of the springing of the arch is not prescribed.

(*d*) The inclination of the approaches shall not be worse than 1 in 16, or than the mesne inclination of the road if that be worse than 1 in 16.

(*e*) The parapets and fences shall be as required above for mail roads.

The width of the present road referred to above is the average available width of *carriage way*, within fifty yards on each side of the centre line.

The mesne inclination is to be taken for a distance of 250

yards from the point of crossing the same. This mesne inclination may be got by dividing the road section into portions which are q. p. straight, and multiplying the inclination of each division by its length, and then dividing the sum of the products by the whole length.

As bridges for private roads almost invariably come under the head of accommodation works, the regulations of these clauses only apply where an accommodation bridge is settled on, either by agreement, or by the arbitrator, without any dimensions or inclinations being specifically mentioned; in such a case the dimensions and inclinations laid down by the Act can be enforced. For this reason, the engineer, when settling accommodation bridges by agreement, or when acting on behalf of the company before the arbitrator, should see that the dimensions and inclinations be described in writing, in the agreement or award, in every case when the bridge or approaches settled on are not in accordance with this Act.

Before availing himself of the powers of this Act, with regard to reducing the width of roads, the engineer must remember, that in case of the authorities, at any future time, widening the road to the limits of twenty-five feet and thirty-five feet respectively, the company can be compelled to widen the arch. In the case of under bridges, the process of widening would be so troublesome and costly that they should be made to the full width at first. In the case of over bridges, the cost of such alteration would be comparatively trifling, and the engineer is justified in availing himself of the reduction in width, in order to reduce the estimate.

No corresponding powers can be exercised against the company to compel them to improve the inclinations of approaches, if made at first in accordance with this Act.

When a bridge is under the railway, the minimum dimensions that can be employed for a stone or brick

arch, in accordance with this Act, are given in the following table:—

	If Segmental.			If Semi-Elliptical.		
	Span.	Rise.	Height of Springing	Span.	Rise.	Height of Springing.
Turnpike Road—widest . .	35	4.50	12	35	4.26	12
" " —narrowest .	30	4.70	12	30	4.36	12
Public Road—widest . . .	25	3.53	12	25	3.27	12
" " —narrowest . .	20	3.87	12	20	3.46	12
Private Road	12	3.73	12	12	3.02	12

CLAUSES Nos. 53, 54, and 55 require that, previous to any road being interfered with, a good temporary road shall be substituted, under a penalty of £20 per diem.

CLAUSE No. 56 limits the duration of such temporary substitution to six months, in the case of a mail road, and twelve months, in the case of a public road; with extension, by permission of those in charge of the road.

The list that I have given above comprises all the clauses of this Act that it is necessary for the engineer to know and remember, when he is designing the details, or superintending the execution, of a railway in Ireland.

There is another Act of Parliament which affects the engineer, when his contract plans and sections are ready, and the company are proceeding to take steps for the purchase of the lands. It is called the "Lands Clauses Act", and will be mentioned further on.

FIELD WORK IN PREPARING CONTRACT PLANS AND SECTIONS.

The engineer-in-chief having re-examined the line of railway, and finally determined on the precise course of the centre line, organizes a staff to execute the survey, levelling, pegging, etc.

The circumstances which guide the engineer in making any deviations are the same as influenced him in the original selection of the route. He has now, however, a more minute knowledge of the ground, gained from examination during the Parliamentary work, and the reports of his assistants. He has also the advantage of the Parliamentary section, by reference to which he can determine on what alterations will be advantageous in reducing the estimate, whether by reducing the earthwork, the side cutting, or the expense of the bridges.

One circumstance may render a deviation imperative, namely, the fact of the crossing of a road being proposed as a level crossing on the Parliamentary plans, but afterwards struck out as such from the bill. This will necessitate a bridge, and the centre line may require a deviation to make a bridge practicable.

The engineer-in-chief now divides the line into portions, as in Parliamentary work, to each of which he appoints two assistants, the one to peg out the centre line and make the contract section, and the other to make the contract survey.

The assistant who is appointed to peg out the line is first sent to the country, and when he has got a few days start the surveyor may proceed to his work. The reason for this is, that as the surveyor's work should be based on the pegs which are put in by the first assistant, and as occasional delays will occur in the process of pegging, the surveyor should not press too close on the assistant who is pegging.

The steps necessary before the letting of the contract and the commencement of the works, may be stated as follows:—

In the field (1) Pegging.
,, (2) Levelling.
,, (3) Surveying.
,, (4) Making map of farms.

In the office (1) Laying down the centre line on paper.
,, (2) Plotting the section and cross sections.
,, (3) Plotting the survey.
,, (4) Marking the land required for the railway, and taking out areas.
,, (5) Plotting line on farm map, and taking out severances.
,, (6) Designing and drawing bridges, tunnels, culverts, etc.
,, (7) Taking out the estimate.
,, (8) Preparing plans for lodgment.

Finally, the arbitration has to be attended, and the accommodation works settled.

I propose to treat each of these processes *seriatim*, in the order of their occurrence.

PEGGING OR STAKING.

In Ireland the chain used is either the 66 feet or 100 feet chain. The latter possesses many advantages over the former, especially in the convenience it affords in calculations of estimates and gradients. The only disadvantage the 100 feet chain labours under is, that it lacks whatever convenience is supposed to appertain to the fact of 10 square statute chains being equal to an acre; that this is of no account I shall show

when treating of acreage. The first thing to be done in the field is, to mark out the centre line of railway, putting in a peg at every distance of 100 feet. The assistant-engineer is provided with an Ordnance sheet, or copy of Parliamentary plans, with the centre line, as ultimately decided on, marked with a fine red line; and his business is, from this guide to mark the line on the ground.

The centre line of railway, no matter how curved, may be considered as a series of *intersecting* straight lines joined by curves, and the process of pegging is based on this view. The assistant engineer first prolongs all the straight lines on his map to their intersections, then transfers these lines to the ground, and lastly fills in the curves. It is a question of practice, or rather habit, with the engineer, whether he puts in *all* the straight lines (that is, pegs fixing their directions, though not the regular 100 feet pegs) first, or follows up his work by putting in the joining curve as soon as he has marked in its two tangent lines. Some prefer one way, some the other. The only reason for the former is the fact of the engineer preferring to make his calculations connected with the curves in the house, in which case time is saved, by simply ranging out the straight lines, and getting the data of the calculations to be worked out in the evening at home. I prefer the latter method, as very little practice enables the engineer to work out his calculations in the field, while it may happen, where a series of curves of contrary flexure occur, that one of the tangent lines, as first laid out, will make the curves overlap, and will require to be altered, perhaps by so doing involving the alteration of more in front of it, *if* they have been all marked out at once *before* this overlapping is ascertained.

A line is transferred from the map to the ground, by putting up five or six poles, or more, according to its length, in

well-defined points on it, such as the crossing of a fence at a measured distance from another fence. When these are erected, with flags on them, the engineer selects two to represent the line, and takes down the rest, putting in pegs at the two fixed on. I may here mention that the men employed are—one to carry and drive in pegs; one to carry the instrument; two to chain; and a boy for running messages and for poles. An engineer can manage with less; but it is bad economy to save cheap labour at the expense of dear time.

In describing the process of pegging, I will suppose that we are watching the engineer in the middle of his work; that he is pegging the straight line from A to B (Plate 1); that he has come up to the point A; and is now proceeding to mark out the next straight line, before putting in the curve. First remark that he stops some distance short of where he expects the first springing of the curve to be, because it would be a loss of time, and source of confusion, should he peg in the straight line beyond the springing point. All pegs so put in would have to be drawn, causing trouble, and, what is more important, loss of time.

He now proceeds to put up poles at c', a point determined by its distance from the intersection of fences; at c'', a point in line of the gable of the house, and a certain distance from it; at d'' and at d', both determined by fences. He now finds that these are nearly in a straight line, and puts in two pegs, say one at c'', and another *near* d'', such that their range will, in his judgment, most nearly represent the direction of the line on his map. I say *near* d'', because the peg at d'' should not be put on a fence, or in any other position rendering it difficult to plant a theodolite over it. Should he find that, from inaccuracy in the survey, or from the points not being well defined, the poles first put up are not in line, or nearly so, he must take an average.

His theodolite, with which he has been pegging the straight line up to A, is situated somewhere on the line AB, set for that line, and with it he proceeds to put in two pegs, *a* and *b*. These pegs, observe, are placed so that the line CD passes between them, and should be only a few feet apart.

As a practical rule, to guard against loss of time, by driving these pegs in wrong places—*i.e.*, so that the line CD will not pass between them,—it is well, when marking out CD, to leave poles at the points c''' and d''', roughly ranging them with the eye; with these poles to guide him, the leading chainman will have no difficulty in putting in the pegs at *a* and *b* properly.

The theodolite is now shifted to the peg at d'', and set to read the centre of the peg at c'', and, then, with it so set two more pegs are put in at *c* and *d*; these should be put in so that the line AB will pass between them.

In putting in *any* peg, the leading chainman first holds up a pole at the spot, and shifts it, as directed by signals (not by *verbal* directions), until the intersection of the wires exactly bisects it; he then gets a peg driven in, and finally holds up the pole again on the top of the peg, shifting as before; and when he has got the point of the pole exactly right, he, by pressure, accompanied by a twirling motion, makes a hole in the top of the peg; this mark, though not permanent, remains for some time, and enables him to hold up a pole again *exactly* in the right spot. Attention to small points like this conduces greatly to the accuracy of the work. All pegs that are intended to be permanent should be driven to within about one inch of the surface of the ground. He now stretches a fine string from *a* to *b*, and from *c* to *d*, and drives in a peg at the crossing. This peg will be referred to as the "intersection peg".

The theodolite is now set up over the intersection peg, and with zero of the vernier clamped to 360°, is directed to the point A, and all clamped.

Another point on the line AB should now be observed, that, by so checking, it may be certain that the point I is on the line AB: this check is essential in the ranging out of all straight lines.

The upper plate is now unclamped, and the telescope reversed, and directed to the point d'', *checking*, as before, on c''. The angle is now read off, and the difference between it and 180° is the "angle of intersection".

Additional accuracy is gained by *repeating* this angle.

The next step is to calculate from this angle, and the known radius of the curve, the length of the tangent, IC, or IB, of the secant IS, and of the curve BC. The line IS is not properly the secant, but is usually entered under that name in the engineer's note-book. Designating the angle *bId*, the observed one, by θ, and the radius by R, these calculations are made by the formulæ

$$BI = IC = R \tan \frac{\theta}{2}.$$

$$Is = R \sec \frac{\theta}{2} - R.$$

$$\text{Length of curve} = \frac{R\ \theta.}{57 \cdot 3}$$

θ, being expressed here in degrees, and decimals of a degree.

For example, suppose the angle θ to be 35° 34′, and the radius of the curve to be 5 furlongs 3 chains, or 3498 feet. The calculations are:

$$\begin{aligned} \log \tan 17^\circ\ 47' &= 9 \cdot 506159 \\ \log 3498 &= 3 \cdot 543820 \\ \hline & \quad 3 \cdot 049979 \end{aligned}$$

which is the logarithm of 1121·96, which is, therefore, the length of each tangent, BI and ID,

$$\log 3498 = 3{\cdot}543820$$
$$\log \sec 17^\circ\, 47' = 10{\cdot}021264$$
$$3{\cdot}565084 = \log 3673{\cdot}52$$

subtracting from this the radius, we find the length of the secant to be 175·52 feet.

$$\text{Length of curve} = \frac{35{\cdot}567 \times 3498}{57{\cdot}3} = 2171{\cdot}3 \text{ feet.*}$$

This length, though not so accurate as that given in the note, is quite sufficiently so for practical purposes.

With the theodolite still at the point I, and under its direction, a peg is put in at B, and another at C, at the proper distance. The engineer then bisects the angle BID. with the theodolite, and directs a peg to be put in at a distance of $175\frac{1}{2}$ feet, that is, at the point S.

These three pegs being in, the engineer returns to the work we found him at, and continues the pegging of the straight line until he has driven a peg within a distance of 100 feet from the peg at B.

Pegging a straight line is such a simple matter as hardly to require description. The only things to be guarded against are, a mistake in direction, owing to the instrument not being firmly clamped, and the pegs being driven in crooked. The former should be avoided by always reversing the instrument, and checking on the back pegs before shifting; and the latter by always taking a sight on the top of the peg, after it is driven.

The instrument should never (except in peculiar cases) be

* If a table of lengths of circular arcs is at hand, the length of the curve is more readily obtained, by multiplying the number in the table corresponding to 35° 34′ by the radius, thus: 3498 × ·6207555 = 2171·40.

shifted to the last peg driven, but to a peg one or two back, so that by reversing a check may be obtained.

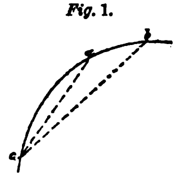
The engineer, when pegging a straight line, is apt to forget the number of the pegs; as a preventative, a good plan is to give a charge to the leading chainman to drive a nail in the "centre" of every tenth 100-feet peg.

Let the peg nearest to B be peg No. 349, and the distance from it to the peg B be 53 feet. The peg No. 350 will be *in the curve*, at a distance of 47 feet from the springing, and similarly the last regular peg in the curve will be at a certain distance from the point C; these two distances are called the "first" and "second" "odd distances", respectively.

The best plan of putting in the pegs along the curve is that known as Professor Rankine's, who, I find, brought it into notice in a paper read by him at the Institution of Civil Engineers, on the 14th of March, 1843.*

This method depends on the fact that at any point on a circular curve the angle subtended by a distance of 100 feet is constantly the same, no matter in what part of the curve the point or distance be taken, and the angle subtended by any other distance is proportioned to that distance.

Fig. 1.



Hence if a theodolite be set up over a point c in the curve, directed to the point a, and then turned through the *constant* angle for 100 feet, the intersection of the wires will come on the point b.

If now, at the same time, one end of a chain be held at a, and a pole at the other end be moved

* There are other methods of laying out curves, some of which I will mention afterwards, and others that may be found in various works on this subject. Some of these methods have advantages under peculiar circumstances; but there is no method that can compete with Rankine's, where the country is close or uneven.

about, still keeping the chain stretched, until the pole appears in the line of the telescope; then a peg put in at that point *b* will be the next peg, and will be *in the curve.*

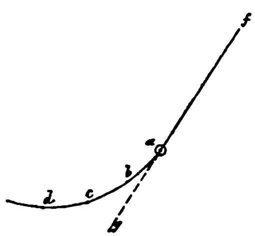
Properly the distance from *a* to *b* should not be 100 feet, but the chord of an arc of 100 feet in length. In railway curves this error is of no account, as the radius is always so large, and in curves for sidings or tramways the error can be reduced by using short chains of 50 feet or 30 feet, or entirely got rid of by using a chain of the length computed for the chord of 100 feet of arc.

The angle subtended by any arc in a circle whose radius is R is equal to

$$\frac{\text{chord} \times 28{\cdot}648}{\text{radius}},$$

the result being in degrees and decimals of a degree.

Fig. 2.



The process, then, of putting in the pegs of a curve is this:—The engineer puts up his theodolite at *a*, sets it for the line *a g*, and turning it through the angle subtended by the length *a b*,* puts in the peg *b*. He then stretches out the whole chain, turns the instrument through the angle for 100 feet, and puts in the peg *c*, and so on. The distance *a b* is what was called above the "first odd distance".

For convenience, ables have been compiled of the multiples of the angle for 100 feet for the usual radii, and also for all odd distances for the same radii. The angle for the odd distance can always be got by multiplying the angle for 100 feet by the odd distance, and dividing by 100.

* The angle between a tangent and a chord is equal to the angle subtended by that chord.

Having these tables so compiled, it is evidently an object to get the instrument to read the first peg *b*, with the vernier at 360°, so that all the succeeding readings shall be identically those tabulated, without any addition or subtraction. This is effected by setting the vernier *back* from 360° through the angle for the odd distance, before setting it to the tangent, and then the reading for the peg *b*, will be 360°. This is for a right hand curve, for a left hand curve the odd distance angle will be set *on*, and the after readings be read back.

Except in rare instances the whole curve cannot be seen from the springing, so that the instrument must almost always be shifted on. The peg to which it is shifted must be one on which the exact position of the point of the pole has been carefully marked. Having shifted the instrument, the best way of continuing the curve is to set it to one of the back pegs, making it read the angle belonging to that peg, and then the vernier is moved to the angle corresponding to the number of the next peg to be put in, and so on. Thus a check is kept on the number of the pegs.

Before starting with the pegging of a curve, the engineer should arrange the details of the curve in his note-book as follows:—

Radius, ...	3498
Angle of intersection, . .	144° 26′
Tangent, ...	1121·96
Secant, ...	175·52
Curve, ...	2171·3
Beginning at . . .	349,53
Secant point at, . . .	360,38·6
Ending at, ...	371,24·3
First odd distance, . . .	47
Second odd distance, . . .	24.3′
Angle for 100, . . .	49.1′

Angle for first odd distance, . 23·1′
„ Second odd distance, . 11.9′

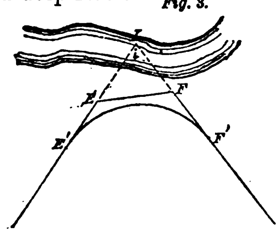
Having these details to refer to at once often saves time and confusion.

The use of the secant point is this: When the pegging comes to it, the line must pass *through* it, and not only that, but it must pass through it at the exact *distance* pointed out by the position of the secant point in the note-book. If either of these checks fail, the engineer should go back at once, and search for his mistake. First, he should try over the angles and distances of his pegs, and if there is no mistake here, he should at once go to the intersection point, and try over his angles and tangent lengths. In the same way as the secant point acts as a check, the second springing also acts as a check. If the work passes these checks, and comes in right, both in angles and distances, the conclusion is certain that the curve is accurately put in, the chances against an error are incalculable. There is much more chance of an undiscovered error in pegging out a straight line, owing to the absence of imperative checks.

Occasionally it happens that the intersection point occurs in a locality where it is impossible to put up an instrument, and sometimes where it is unapproachable at all.

The intersection may come, for instance, in the middle of a deep river.

Fig. 3.



In this case the method of procedure is to put in pegs E and F at any two convenient points on the straight lines, the line EF is then to be chained, and at E and F the intersecting angles EEF and EFF′ are observed. The sum of these two angles, minus 180°, is equal to the true "*angle of intersection*". The lengths of E*i* and F*i* are next calculated:

$$Ei = \frac{EF \sin EFF'}{\sin i}$$

$$Fi = \frac{EF \sin FEE'}{\sin i}$$

These lengths, and the length of the tangents, having been calculated, the differences between them and the *tangents* are laid off from E and F, respectively, and the springings put in, and the curve pegged as described before.

In this case we are deprived of the advantage of the secant point, which, however, it must be remembered, is merely a check on errors to save time, and not essential.

Professor Rankine, in a paper read before the Civil and Mechanical Engineers' Society, December 6, 1860, gives, besides other interesting problems, a method of ascertaining an additional point in the curve, which will serve the object of the secant point in the ordinary case. The paper referred to is given in the *The Engineer* of January 4, 1861.

Fig. 4.

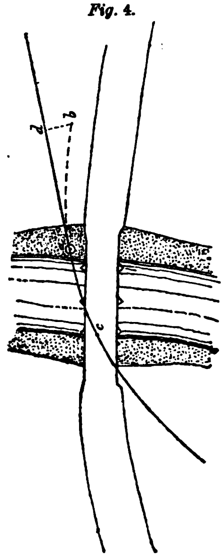


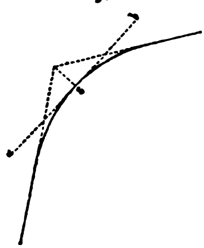
Figure 4 shows another peculiar case, where the springing, *a*, is situated on low land close beside a high bridge. The curve cannot be pegged in the ordinary way, but the difficulty may often be got over by pegging backwards a continuation of the curve until a point *b* is reached from which the curve at *c* is visible.

If *a* be so situated that the curve cannot be pegged even backwards, then a point *b* may be got by taking any length on the tangent, and laying off the offset *bd* at right angles.

$$bd = R - \sqrt{R^2 - (ad)^2}$$

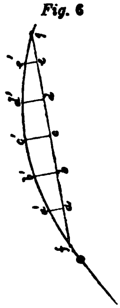
All that is wanted is a point b *in the curve:* its *position* in the curve is of no importance, and the point d may be selected to suit the ground.

Fig. 5.



It may happen that *both* springings come on places where it is impossible to erect the theodolite. In this case the secant point s must be put in very carefully, and the instrument erected over it, and the curve pegged in backwards and forwards from it, taking as tangent a line ab at right angles to the secant line.

Fig. 6



Again, it may often be found impossible to bring a curve continuously round a precipitous face of a hill. In this case a chord of great length should be carefully laid off from the springing, or some other point in the curve, so as to pass over accessible ground. This straight line should be carefully ranged and chained, and the points a, b, c, etc., marked, so that rectangular offsets will pass through the proper 100-feet pegs of the curve.

The distances fa, fb, etc., should be carefully calculated, and are got from the following formula.

$$fa = 2R \sin\left\{\frac{fa' \times 180^\circ}{2\pi R}\right\} \cos \frac{ga' \times 180^\circ}{2\pi R}$$

The distances fa, fb, etc., having been calculated, the engineer puts in pegs at a, b, c, etc., and afterwards goes over the line and sets off accurately at right angles the offsets aa', bb', etc., which are thus got

$$aa' = 2R \sin\left\{\frac{fa' \times 180^\circ}{2\pi R}\right\} \sin\left\{\frac{ga' \times 180^\circ}{2\pi R}\right\}$$

These offsets, if small, may be got to a very close approximation, by a rule that does not require tables,

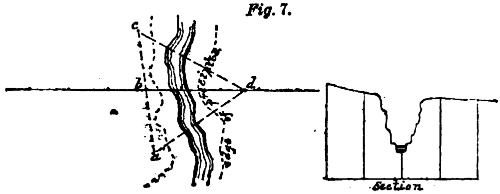
$$aa' = \frac{fa \times ag}{2R}$$

or, if the offset be large, and perfect accuracy required

$$aa' = \sqrt{fa.ag + R^2 - \frac{fg^2}{4}} - \sqrt{R^2 - \frac{fg^2}{4}}$$

In pegging out a straight line, the engineer may come on a steep ravine, with precipitous sides, say 80 feet deep, and 700 feet wide, which it is necessary to peg and measure along the centre line. In this case it may be useful to determine a point on the centre line at the opposite side of the ravine by triangulating from a line on one side. The diagram shows, by the dotted lines, the operation necessary.

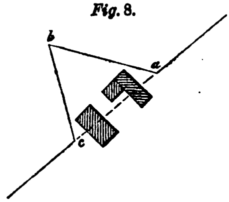
Fig. 7.



The line *abc* is to be chained, and the angles at *a*, *b*, and *c* observed, from which the distance *bd* is calculated. In the direct work, then, this serves as a check on the chaining up and down the ravine. The section shows the nature of the ground and position of the pegs.

Again, the engineer may come on a wood, which he cannot, under special circumstances, cut a way through, or a lot of houses of which possession cannot be immediately obtained. In this case, when he comes to a point (*a*) near the obstacle, he lays off a line (*ab*), and measuring the angles at *a* and *b*, cal-

Fig. 8.



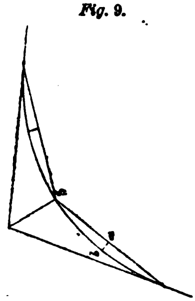
culates the length of $b\ c$, and starts again at c with the calculated angle at c. If this operation be repeated at the opposite side of the obstacle, or a tie-check be introduced, great accuracy can be obtained, and time saved.

The pegs having been all put in, the engineer next puts down the centre line on paper for the use of the surveyor, going through the same processes that he has used in the field.

Owing to curves, the whole of the centre line, except on very short railways, cannot be continuously laid down on the one roll of paper, without making the roll inconveniently wide. It is, however, useful to get as great a length as possible of the centre line on the roll without a break. The easiest way to do this is to cut a piece of tracing paper to the dimensions of the roll, reduced in the proportion of the contract and Ordnance scales, and by shifting it about on the Ordnance map, get the best position for the centre line, and then transfer that position to the large roll.

The tangent lines are then laid down, the springings marked, and the curve ruled in. The best way of laying off the intersection angles is to mark off on one tangent a measured distance, calculate the length of the tangent of the angle of intersection to that radius, and lay off that distance at right angles to the tangent; this is far preferable to the use of even the best protractor.

Fig. 9.



Having marked the second springing, the centre line is then ruled in with the proper curve.

Should the curve not be long enough to stretch from one springing to the other, the secant point must be plotted; and, should this not be sufficient, additional points must be got as follows:

The secant point having been laid

off, a line is drawn from it to each springing, and at the middle point of each of these lines, the distance *a b* is laid off. If no wooden or metal curve be available cut to the exact radius, a number of points may be plotted as above, by subdividing the arcs, and the curve then ruled in with the nearest curve.

The odd distances are then marked off from each end, and the intermediate pegs marked in. Owing to the difficulty of repeating distances accurately along a curve, the latter process requires some care, and should be done with a spring compass, which can be adjusted to make the pegs come in right, and keep them equidistant.

Great exactness is necessary in laying down the centre line and in marking the position of the pegs, as the plotting of the survey depends on their accuracy, both in position and distance.

Finally, the engineer who has pegged out the line, makes out a list of the curves and their details, for the use of the engineer who is appointed resident on the works.

LEVELLING.

When he has finished the pegging of the line, and laid down the centre line for the surveyor, the assistant proceeds to level for the contract section.

Starting from a benchmark at one end, he proceeds along the pegged line, taking levels on the top of each peg, and also at each alteration in the ground level between pegs, which he thinks amounts to one foot or more, noting in his book the measured distances at which such observations are taken.

He should also note the exact distance at which the centre of every fence crosses the centre line, and also, either by a

sight, or by measurement, the height of each fence and depth of each gripe. The section thus becomes a check on the survey.

The importance of the fences being shown on the section at the proper pegs and distances, is greater than may appear at first, as when the works are being carried on, the only thing the managers or engineers of the contractors have to guide them, is a copy of the section: hence a fence being shown at the wrong peg may lead to confusion and mistakes.

While levelling, the engineer should watch carefully that no peg is skipped. The system of pegging described above insures no mistakes being made in the number of pegs on the *curved* portion of the line; but no check exists on the accuracy of the number of pegs put in on the straight portions, except what will probably, but not necessarily, be furnished by the survey.

When he meets with any stream, the engineer should be very particular in noting the width and depth, the way in which it flows, and the average rate of fall. He should also measure the water-way of the nearest culvert or bridge over it on the down-stream side of the railway.

Having levelled over the entire of this section, the engineer proceeds to check his levels. As a general rule, it is better to check back on every peg. This takes but little more time than if he merely took the longest checks, and if any difference does occur, at once points out the exact spot where the error is. Another reason for checking on every peg is, that without it no check at all exists on the levels of those pegs that are points of intermediate sights when first levelled.

If the engineer has a middle district to level, he cannot fill up the column of reduced levels until the level of some common bench-mark has been given to him by the engineer on the district before him; but he can reduce his book to a datum of his own in a column on the far side of the right-

hand page, for convenience in comparing the original with the check levels.

Plate 2 shows part of a contract section, with a page of the field-book used in levelling.

Check levels should not show a greater discrepancy than one-tenth of a foot per mile.

Every change of the position of the instrument in levelling should be made with the staff on a peg-head or bench-mark. In windy weather, if reading high, the staffman should be taught to slowly wave the staff backwards and forwards in a line with the instrument, when the engineer can easily catch the true, *i.e.* lowest, reading.

Having completed the levelling of the longitudinal section, the engineer proceeds with the road sections and cross sections.

The road sections should be so taken as to show the surface line of the present road, and also, if the road be proposed to be diverted in any way, the surface along the proposed altered route. In either case, if the ground on either side be uneven, cross sections must be made.

Occasionally, particularly in the neighbourhood of bogs, roads will be met with that stand at a pretty uniform height over the general surface of the ground: when making a road section in such a case, a reading at each distance should be taken on the side as well as on the road, and the general surface shown on the road section, when plotted, by a dotted line.

As the road sections are generally made before the contract survey has been plotted, the engineer is often at a loss to know what is to be done with a road, whether it is to be diverted or not, and what course the diversion will take. In this case he should make a series of sections at short intervals parallel to the centre line, from which a true section can

be produced in the office along the deviated course, when settled on.

The engineer will find it useful to have with him, when making road sections, a copy of the Parliamentary section, to enable him to form some opinion, making allowance for alterations in the course of the centre line, of the length of section required on each side of the centre line. He should note particularly if any substitution of a bridge for a level crossing has been made in the act, as the section will require, in that case, to be much longer. Road sections need not be either reduced or plotted to any particular datum; each may have a datum of its own; but each section must include a reference to some peg or bench-mark by which the height of formation level may be plotted on the road section.

After (or, if he prefer it, before) making the road sections, the engineer should make cross sections at every peg, except where the ground is quite level. These cross sections are very important, as on them depends not only the quantity of earthwork, but also the width of ground taken. A more annoying thing can hardly occur to a resident engineer than to find that too little land has been taken, necessitating expensive extra works, or the purchase of more land at an exorbitant rate.

PLOTTING THE SECTION.

The engineer who was charged with the pegging and levelling, now comes up to the office, and plots his sections and cross sections, after which his special work is finished.

Longitudinal sections are plotted usually to a horizontal scale of 200 feet to one inch, and a vertical scale of 20 or 30 feet to one inch; the latter is preferable, as it is amply large

for showing an alteration in level of 3 inches, and its employment on a long section often saves breaks, or alterations of datum, necessary to keep the section within a convenient height. The plan and section must always be on the same horizontal scale.

The engineer who has levelled the division adjoining the reference point for the Parliamentary datum, under the directions from the engineer-in-chief, fixes the datum line, and ascertains exactly the difference between it and the Parliamentary datum. When he has then reduced his book, he communicates the reduced height of his last peg, or, better still, of a bench-mark, to the next engineer, who in his turn hands on the datum to the next. If the books have been reduced already, as I suggested above, the datum can be communicated to all the men engaged in a few minutes.

The first care of the engineer in plotting the section is to obtain a perfectly straight datum line.

Having joined a sufficient number of sheets of paper for the length of his section, he stretches the roll out on a long table, and marks points for the datum line. This is most correctly done by stretching a thin black silk thread from one end to the other, over that part of the paper where he wishes the datum line to be drawn, taking care to keep it when stretched clear of the paper, and then marking points along it at such distances as he can join with a true straight edge. He then rules in the datum by a fine line in Indian ink.

He next marks along this line the position of every peg, and draws rectangular ordinates with a fine pointed pencil, and then numbers every fifth peg, counting from the commencement of the line.

The engineer, for his own convenience and that of the surveyor, must in the first place number the pegs of his division of the line independently, and without regard to the divisions

before him; but when figuring the section, the numbers must count from the commencement of the railway, or of a division of the railway, if it be divided into separate contracts. He should also put in his field book, opposite each peg, the true number that it bears on the section when plotted.

Besides the ordinates at every peg, he should draw pencil lines for ordinates, at the distance of every observation in his levelling book.

Having plotted all the heights on these ordinates, he joins the points, taking care to put in all fences, drains, and walls, as shown by the notes he has made in the right-hand pages of his book.

The ordinates at every *peg* are then ruled in with Indian ink, from the datum line to the surface of the ground, and the reduced heights of each peg marked on the left-hand side of each ordinate near the datum line.

It will occasionally occur that in pegging, the pegs are put in places which do not truly represent the surface of the ground, as in the tops of fences, in haystacks, and sometimes in the roofs of houses. In such cases, two reduced levels should be given if possible, one of the peg and another of the surface of the ground. If, as often happens, the pegged line runs for a considerable distance along the top of a wide fence, the section of this fence should be shown by a dotted line, and the true surface of the ground by a hard line.

The next thing is to write the words, "farm road", "public road", "river", "stream", "mill race", "avenue", etc., wherever such occur.

The section is now ready for gradients, which cannot be well put on before the road sections, cross sections, and survey are plotted, as each of these must be taken into consideration by the engineer when fixing the gradients. Borings must also be made in order to ascertain the nature of the

ground; these borings must be made at such distances and places as are directed by the engineer-in-chief.

The parliamentary gradients should now be marked on in pencil, as a guide to the working gradients, or rather in order to show the limits to which the working gradients may be deviated from them either in position or inclination.

As a general rule, the gradients should be laid down so as to give the least amount of work, at the same time, of course, not exceeding what the engineer-in-chief considers should be the ruling gradient, nor exceeding the limits laid down by Railway Clauses Act.

What was mentioned in Part I. about the introduction of tunnels applies equally in the case of contract sections.

In cases where gradients causing heavy cuttings, without corresponding embankments, are unavoidable, dwarf walls are often introduced with economy, but only in cases where the cutting is in clay, and to be run to spoil. In such cases there is a particular height of cutting at which the cost of the walls is equivalent to the cost of excavation avoided. This height is given by the equation—

$$h=\frac{\frac{2p}{P}+w^2r}{2wr+B-b}$$

where h is the height of the cutting, B the ordinary base of excavation, r the ratio of slopes, w the height of the wall, b the width between the walls, P the price per cube yard of excavation, and p the price per yard run of the dwarf wall. For any greater height than h a saving is effected by the introduction of dwarf walls.

Rivers, streams, accommodation works, and, above all things, mail-roads or public-road bridges, must be considered when marking the gradients, the efficient drainage of the

latter, if under the railway, being a matter of primary importance.

If the country be uneven, the cross sections will materially influence the quantities of cutting and embankment, and consequently should be plotted before the gradients are laid down.

Cross sections are always plotted on a natural scale, that is, the same vertical and horizontal scales, usually 20 feet or 30 feet to one inch. As soon as the height of cutting or embankment has been ascertained a line is drawn showing formation level *for a double line*, and the slopes drawn in. From the edge of each slope is then set off a particular distance, *measured horizontally*, depending on the kind of fence to be used, and a mark made to show the boundary of the land required to be purchased. If the line be single, the slopes for the single line should also be plotted.

Though the line is intended to be a single line, land is nearly always taken for a double line.

Afterwards the width of formation level for the single line, on the side on which it is intended to be made, should be marked on the cross sections, and the slopes drawn, and also a line marking the separation between rock and clay, if rock be shown by the borings.

The road sections should also be plotted before the gradients are fixed: they are usually drawn to a scale of 20 feet to one inch vertically, and 100 feet to one inch horizontally.

Wherever stations occur, a horizontal portion, if possible, should be provided of, at the least, 700 feet, but the longer the better. *Ceteris paribus*, the best section for a station ground shows an average of four feet of *cutting*.

A sharp gradient falling *towards* a station, should if possible be avoided, but is not by any means objectionable, if falling *from* the station. If a station *must* be put in the middle of a

gradient, the inclination of part of the gradient must be increased, and the increase should always be made on that portion of the gradient that falls *from* the station.

The gradients having been marked, the next thing is to mark in figures at each peg the height of formation level at that peg, and also the difference between the height of formation level and the level of the peg. Three rows of numbers have thus to be put on the section, one denoting the reduced level of each of the pegs, another of the formation level at each peg, and the third, the difference of the two; the latter showing the height of embankment or cutting required at each peg. According to the wish of the engineer-in-chief, these three rows are put at the foot near the datum line, or the two former below, and the latter on or near the line representing formation level.

The copy of the section furnished to the contractor has only the one row of figures, that of cuttings and embankments.

The heights of formation level, and indeed the other heights, are never given to more than two decimals of a foot; but when marking the reduced heights of formation level, the engineer should make on a separate paper a list of the heights, from one change of gradient to the next, to four decimals, and then enter on his section the two decimals most nearly corresponding.

The exact position of each springing of a curve should be marked on the datum line by a point, with a small circle round it, and a number denoting the distance of the springing peg from the preceding 100ft. peg. The radius of the curve and the words "curve begins", or "curve ends", should be written above the section, vertically over each springing.

The rates of inclination of each gradient, and the height of every change of gradient should be marked.

The distance from the commencement should be marked below the datum line every quarter of a mile.

As soon as the borings have been made, they should be marked on the section, with notes as to the nature of the ground.

SURVEY.

The survey of lands for railway purposes is conducted in the same way as ordinary surveys, but possesses some special features.

In ordinary surveying, whether with the chain alone or with the aid of instruments, the process may be generally defined as consisting in the laying down of main lines, the construction on them of triangles upon triangles, and finally the filling in of the details.

Railway surveying is never so complex. The surveyor, coming as he does after the engineer, who has put in the pegs, is thereby supplied with an accurately ranged and measured base line on which to found his work.

There are two forms of note books used in surveying, one a large square book in which the whole work is sketched, showing the working lines, offsets, and fences, and the other a long thin book opening at the end with columns ruled in each page.

The method by sketch-book requires no explanation: it requires a great deal of experience to keep the book neatly and distinctly.

In the other method, each page is ruled, as shown in Plate 4, and contains the distances and offsets measured along any one line of the survey; the position of that particular line being fixed by the description of the beginning and ending of the line.

The space between the red lines must be considered as imaginary, and the page must be looked on as if cut in two down the middle, and the halves separated by the width of the middle column.

If the engineer adopts the latter of the two methods of surveying, it will conduce greatly to clearness and speed in plotting to adopt the following plan.

One end of the book should be kept for the survey of the pegged line, showing at the same time the general plan of chain lines adopted, and the method, whether tie-lines or angles, by which each point is fixed, designating the points by distinctive letters or figures. At the other end of the book the chain lines themselves are entered, and distinguished by the description at the commencement of each, as, for instance, A to B, E to peg 184, 186 of AB to 230 CD, etc.

Plate 4 shows a page from each end of a book kept in this way. All pages should be numbered from both ends, and only one side of a page used.

The engineer must be guided by experience in laying out a system of chain lines that will give him the survey with the least amount of labour, and consequently in the least time. He must decide on these lines from the Ordnance map or parliamentary plan.

A point may be determined by two lines, one line and an angle, or two angles, but should never be left without a check, either a tie-line or a check-angle.

Offsets may be taken with a tape, but should not exceed 100 feet, except in rare instances, and then should be laid off with an optical square.

The engineer must be *most* particular about fences, houses, and roads within a distance of one hundred feet of the centre line; the parts of the survey further away do not require such accuracy, except in the case of roads which cross the railway.

As a general rule, the survey should extend to four hundred feet on each side of the centre line, and the fields to that extent should be closed. The fences are to be shown by single lines on the plan, and the position of that line is determined by the custom of the place. For instance, in some counties of Ireland, the boundary, which is represented by the line, is always in the centre of the mound of the fence; in others it is on the outside of the gripe.

The engineer should consult Williams' *Geodesy* for information about surveying in general. He will find there also most of the difficult cases that arise, and methods of surmounting them.

When the surveyor comes to plot his work, he gets the paper for it from the engineer who had pegged the line, with the centre line laid down, and each hundred-feet peg, as well as springings, marked.

The centre line should be marked in Indian ink, which stands the rubbing which the plan must undergo much better than blue or red ink, both of which are sometimes used.

After having plotted the survey, the engineer inserts the townland, parish, and county names, and their respective boundaries, in the same characters as they are distinguished by on the Ordnance map.

The next step is to put on the reference numbers; these should exactly correspond with the ones on the parliamentary plans.

Occasionally it will be found, that the contract plans differ from the parliamentary plans, owing to changes that have been effected in the lands between the times of the two surveys; fences may have been thrown down and two fields thrown into one, or new fences made, and new enclosures formed. In the former case it is better to put both numbers on the contract plans, putting each number in about the same

position as it occupied on the parliamentary plan, and in the latter case new numbers must be inserted, such as 17*a*, 17*b*, etc., care being taken that these do not occur anywhere else on the *parliamentary* plans in the same townland.

The survey is now ready to have the land required for the railway marked on it. For this purpose the engineer makes out a table of side-widths, showing opposite each peg the width of land required on each side of the line.

Where the land is level, the side-widths are got by adding to the height of cutting or embankment, multiplied by the ratio of slopes, a constant which depends on the width of formation level and the kind of fence determined on by the engineer-in-chief.

Where the land is sidelong, the side-widths should be taken from the cross sections, measuring horizontally, and taking care that the widths, if different, are plotted on the proper sides of the centre line.

If the section be very rough, side-widths should be also plotted, if required, at intermediate points between pegs.

When the side-widths are marked off on the plan, they should be all connected by a fine pencil line, and *checked.* If any roads are to be deviated, the land required for them, or for approaches to bridges, should next be marked, and then the boundary of the land required to be purchased marked with a fine red line, and the land coloured red.

The number of every fifth peg should next be marked, and the acreage ascertained of all lands required to be purchased. The acreage is usually made out in statute measure, and marked in both statute and plantation measure on the plan.

The acreages that have to be calculated are always small, rarely exceeding two acres, so that by bearing in mind the number of square feet in one acre, 43,560; in one rood, 10,890; and in one perch, $272\frac{1}{4}$, the engineer, will find that

the calculation will be effected as easily as if the divisions on the scale represented links. However, if he should prefer working in links, he can do so by getting a corresponding scale to measure with. Thus, if the plan be made on a scale of 200 feet to one inch, a scale of 30·303 divisions to an inch will give the measurements in links.* When all the measurements of works made by the engineer are in feet, or multiples of feet, the advantages of the 100-feet chain are so great as to completely overbalance the slight convenience of having the plan plotted to links.

Every field, stream, private road, house, or enclosure of any kind, should have a separate acreage.

Public roads are usually measured into the adjoining lands, half to each side.

Finally, the plan and section is sent to the lithographer, and lithographed in sheets, each containing about fifty pegs of both plan and section.

FARM MAP.

Before the land is bought, or the arbitrator appointed, the engineer must provide an Ordnance map, showing the land required for the railway, the extent of the farm of each occupier, and the quantity of land that is left in each farm, on each side of the railway. This is required for the arbitrator, as one very important item in the purchase-money of land for railway purposes is the cost of consequential damage; and this depends, among other things, on the deterioration in value per acre of the severed portion of the farm.

In preparing this map, the engineer must go to the country,

* These scales can be procured from Messrs. Elliott, 30 Strand, London.

and walk over each of the farms, as pointed out by the occupier, and make any corrections that may be required in the boundary line of the farm, inserting any new roads, dwelling houses, etc., that are not on the Ordnance map. The corrections made for parliamentary work will be of some use, but the farms will always stretch far beyond what was then corrected.

If there be any timber on the farm, he should ascertain whether it is included in the tenant's holding.

Having coloured the land required for the railway red, and the farms with distinctive colours, he writes on each farm the amount of land required for the railway, the amount of land on each side of the railway, and the tenant's name.

LODGMENT OF CONTRACT PLANS, AND PURCHASE OF LAND BY ARBITRATION.

Before the company can get any land by their compulsory powers, plans must be lodged, as enumerated below.

The Lands' Clauses (Ireland) Act, 14 & 15 Vic., cap. 70, requires a copy of the *plans* and of the *schedule of valuation*, both signed by the engineer-in-chief and the secretary, to be lodged at the office of the Board of Works, and also copies of so much as lies in any county or union with the clerk of the peace of such county or union. This Act regulates the scale on which contract plans are to be made, namely, not less than 200 feet to one inch. Accommodation works proposed by the company are to be shown on these plans; but as it is open to the company to propose other works before the arbitrator, and to the arbitrator to alter any such works proposed, it is not of any importance to have all the works which the engineer considers necessary for the accommodation of each farm

shown on these plans. The engineer must be cautious in marking these works, as he cannot well get them altered afterwards.

The sections should always be cut off the sheets, when lodging plans, except in the one case, referred to before, of lodgment with the Drainage Commissioners.

The process for obtaining land under the Lands' Clauses Act (Ireland) is, in practice, as follows:—

The engineer furnishes the valuator employed by the company with a set of plans, on which are marked the tenants' names, and the boundaries of the farms coloured. The company's valuator then goes over the land, and prepares his schedule for lodgment, which shows opposite every number the acreage of land taken, the names of all interested in the lands, and the money which he thinks fair compensation for the land taken from the company, and for consequential damage, proportionately divided among those interested. These schedules should be compared with the plans in the engineer's office, to see that no number, if affected, is omitted, and that the areas are right.

The Board of Public Works, after the lodgment of the plans, appoints an arbitrator to decide on all cases not previously settled by agreement.

Notice is then given by advertisement, that an inquiry will be held, and a draft award prepared by the arbitrator, and lodged in the same way as the plans.

After an interval a second inquiry is held, and a final award lodged as before.

The company can now get compulsory possession of the land required, even though the party in possession refuses the sum named in the final awards and enters a traverse at the assizes; so that each person interested in the land may settle by agreement, go before the arbitrator at the first in-

quiry, go, if still dissatisfied, before the arbitrator at the second inquiry, and finally may try the case at assizes.

The money question does not concern the engineer; but at each of the times above mentioned the question of accommodation works also arises.

Before the arbitrator the engineer acts on behalf of the company, giving evidence of the position, cost, practicability or the contrary of proposed works, and on other engineering points. He is sworn and examined and cross-examined. He should be well acquainted with the ground along the line, so as to be able to speak confidently about proposed works, as, for instance, about the drainage of works under the railway, and the proper inclinations and widths to be given to bridges over the railway. He should be prepared with the approximate cost of accommodation works.

When the arbitrator decides on any work as necessary, the engineer should ask to have it so fixed as to prevent any dispute hereafter. The precise spot, referred to the pegs, should be mentioned, and the precise dimensions of any work not in accordance with the regulations for private road bridges. It is not sufficient to have a cattle-pass put in the award as "10 ft. × 8 ft."; it should be "10 feet high and 8 feet wide", or *vice versa*, as the case may be.

If bridges are to be built for accommodation of the lands, the ground required for the approaches should be inserted in the award, or a note put to the effect that the owners and occupiers are to give the ground. If there is any doubt about the drainage of an under work, the onus of draining should be thrown on the occupier.

As soon as the plans and sections have been lithographed, the engineer should mark on two copies the culverts which he proposes to build. One of these copies he sends to the solicitor, with a request to have it lodged with the Drainage

Commissioners. Soon afterwards he will receive a schedule from the commissioners, with a request to have it filled in with the details of the culverts, and a demand for the second set of plans. When these have been sent to the commissioners, they appoint an engineer to examine the line of railway, and to report on the culverts proposed, and from his report compile a schedule, which they *sign* and send to the engineer with one of the sets of plans. The schedule thus certified must be complied with; but, at the same time, the engineer must remember that bare compliance with it will not protect the company against actions for deficient drainage.

It is an important point that the lodgment with the Drainage Commissioners is the only case in which the engineer should lodge the *section*.

DRAWINGS.

Preparatory to taking out the estimate, drawings must be prepared of all public road or mail road bridges over or under the line, of all river bridges, of culverts, of cross-sections of railway in clay and rock cuttings and embankments, cross-sections of road approaches, of level crossing-gates for public roads and farm roads, and drawings of tunnels, if any.

Of course, the drawings for bridges never are made according to a fixed rule, the previous works of the engineer-in-chief, and alterations introduced by him, chiefly regulating the designs. The engineer-in-chief decides what bridges are to be stone or brick, and in what bridges it will be advisable to introduce cast or wrought-iron superstructures.

An explanation of the terms employed in bridge building may be useful to beginners. Taking an over bridge as in Plate 3:

"FOUNDATIONS" are the masonry laid below the ground and up to the level of the upper footing, or projection.

"ABUTMENTS" are the masonry from the foundations up to the beginning of the arch. When two arches abut against one another, the two abutments become a "pier".

"SPRINGING" is the line at the top of each abutment where the arch meets it.

"SPRINGERS", or "springing course", is the top course of stone on the abutment, and becomes the

"IMPOST", when formed of projecting nicely-dressed stones, plain or moulded.

"ARCH-SHEETING" is the masonry forming the arch for a particular depth, as shown by the cross-section; the face stones of the arch-sheeting are called

"RINGPENS", which are the courses of face stones at each side of the arch.

"SOFFIT" is the concave surface of the arch.

"INTRADOS" is the lower line of the face of the arch, and

"EXTRADOS", the upper line of same.

"VOUSSOIR" is a term for the face of a single ringpen. Voussoirs are not shown on drawings, except of very elaborate and large bridges.

"WINGS" are the walls built to keep back the earth on each side of the bridge. Wings may be either curved or straight, and the latter may be either "straight back", or "splayed"; "straight back", when they are parallel to the rails, if an under bridge, or to the road, if an over bridge; and "splayed" when running nearly at right angles to these directions. Wings are sometimes terminated by a return, or by

"NEWELS", which are built at the end, with horizontal tops, and covered with newel-caps.

"SPANDRIL" is the space between the arch-sheeting and the top of the bridge, and bounded by the

"SPANDRIL WALLS", which may be external or internal.

"HAUNCHING" is the masonry that is put back, or over the "haunches" of the arch, and supports the internal spandril walls, if any.

"SPANDRIL ARCHES" are the arches covering the spaces between the internal spandril walls.

"STRINGCOURSE" is the course of dressed stone that caps the outside spandril wall, and supports the

"PARAPET", which is the side wall of the road or railway.

"COPING" is the course of dressed work, which is always put on the top of each parapet, and also on the top of each wing.

"PILASTERS" are vertical projections, which occur in wings and parapets.

"PUDDLE" is a coat of stiff clay, usually put over the masonry of the arch, to prevent water draining into it.

"CAPS" and "BLOCKS" are dressed stones in positions indicated by their names.

"BLOCK-IN-COURSE" is coping of the nature of a continuous "block".

"COUNTERFORTS" are vertical projections at the back of each abutment, built to receive the thrust of the arch.

The considerations which regulate the employment of stone, brick, or iron in the construction, are two-fold—the abundance or scarcity, cost, etc., of the material itself, and the convenience afforded by the form in which the material can be applied.

Generally speaking, throughout Ireland, there is no lack of good building stone; but places do occur where *good* stone is not to be got within a reasonable distance, and where either brick or iron must be employed. I leave wood out of the

question, as I believe it s generally allowed by engineers now, that there is no worse economy than employing timber in any bridge that can be erected of any other material.

Though stone bridges, *ceteris paribus*, should be adopted if possible, yet the consideration of height may so influence the question as to lead to the adoption of iron bridges, even where stone is plentiful. In the case of over-bridges, the reduction of the height may be of great importance as reducing the quantity of the embankment, or shortening the length of the approach. In under-bridges it may be of still greater importance, allowing a reduction in the height of an embankment, which should perhaps have to be made from side cutting. Iron bridges may also be adopted for another reason, on account of any insecurity in the foundations that would render some slight settlement in the abutments probable. An arch might be seriously damaged by a settlement that would in no way affect an iron superstructure.

When the description of bridge, and the angle at which it crosses the railway if an over-bridge, or the road if an under-bridge, have been determined on, the engineer proceeds with the drawing. Suppose, for instance, that he is engaged on an over-bridge, such as is given in Plate 3, with splayed wings and a segmental stone arch.

I may observe, that in designing a bridge, all the parts of the drawing must be carried on together, neither plan nor elevation can be finished by themselves, without having the sections drawn, or as vividly impressed on the mind as if they were drawn.

The first lines to be drawn are the centre lines of both road and railway on the plan, and the formation level and surface of ground on the elevation. The "section through the abutment and arch *on the square*", should then be drawn, and also the general cross-section of the wings.

In drawing the cross-section of the abutment, the dimension of the foundation courses will depend on the nature of the ground, but they generally are wider than the abutments, and terminate in a footing at one foot below formation level, and projecting at least nine inches.

Even where no additional width of bearing surface is required, the footing is usually put, so as to afford a fair level surface on which to start the next work.

The footings in over-bridges should be at least one foot below formation level, to enable the water tables, or side drains, of the railway to be carried continuously through the bridge. The projection of a footing depends on the material employed; every front stone in a footing course should be at least as much embedded in the work as it is exposed, else the footings lose their value, which is to spread the pressure: hence the projection mentioned above may be increased, or must be diminished, according to circumstances. If a greater width of foundation be thought necessary, it must be gained by increasing the number of the footings, and not their width.

The height of abutment, and span, and rise of arch, I suppose prescribed for the engineer. The radius of the circle of which the arch is a segment, is given by the equation,

$$R=\frac{r^2+s^2}{2r}$$

where R=radius, r the rise, and s the semi-span of the arch. In segmental arches of moderate span, the extrados is usually struck from the same centre as the intrados. The thicknesses of the arch and of the abutments have been the subjects of theoretical investigations, but practially depend on previous examples. It is possible to determine the width of an abutment that will just keep the arch in equilibrium, but this has to be modified by a *coëfficient of safety* (in itself very variable), so that the value of the theoretical rule is practically lost. The

haunching is usually carried up at the back in a plumb line with the abutment, terminating at a point one foot or more below the soffit of the crown of the arch, and raked from that in a line tangent to the extrados, to allow water to run freely off. Steps are sometimes introduced to lighten the haunching.

The counterforts are shown in section at the back of the abutment, and are usually plumb at the back. Sometimes they are raked off in a line with the haunching, and sometimes are stopped lower down. Their object is to help the abutment to withstand the thrust of the arch. There is no use in founding counterforts as low as the abutments, when the bridge is in cutting, they should go down to a good foundation for themselves. They may or may not have footings. The puddle is usually shown six inches deep, and should extend over the counterforts.

From this section the abutments and counterforts can be marked on the plan, and projected to the elevation. The elevation of a skew arch is properly a segment of an ellipse, but generally is drawn in as a circular segment.

In the bridge under consideration, the next step is to draw lines at the distance back from the front of the abutment at which the wing is to be splayed, and then lines parallel to the centre line of road, indicating the intersection of the wing with the newel.

Before this last can be done the "section through the crown of arch, viewed on the square" must be drawn, and the elevation of the wing on the square plotted. The intersection of these four lines will then give the extreme points of the wings. If the wings be battered, and also stepped in the foundations, a point (*a*) must then be laid off at a distance equal to the batter due to the height of the end of the wing over the foundation of the abutment, and a pencil line drawn

from it to b, the point at which the lower part of the wing joins the abutment. The distance from b to the corner of the abutment usually is at least one foot, sometimes more. If it be made very small, a practical difficulty in building is introduced, and, except at great expense, bad cross bonding into the abutment induced. The lines representing the footings of the different steps of the wing will be each parallel to the line ab, standing back from one another at a distance equal to the batter of the height of each step over the one below it. To get the top of the wing, the point f is laid back from ab, at a distance *on the square* equal to the batter of the highest part of the wing.

In the design in Plate 3, it will be seen that the parapets are curved, and consequently the point e is lower than the crown of the extrados; the curve is so regulated as to have, at the points immediately over where the wings join the parapets, tangents at an inclination of 1 in 20, this being for a public road, and consequently the radius of this curve is equal, *quam proxime*, to $ce \times 20$, and in other cases equal to ce multiplied by the inclination of the approaches.

With this curve in the parapets, the point e will be lower than the crown of the extrados by a height

$$\text{equal to } \frac{ce}{2 \times \text{inclination}}, \text{ in this case } \frac{ce}{40}.^*$$

The point f then having been got, the plan of the top of wing immediately under the coping is drawn in. In this bridge there is a "return" of the parapet, and the portion fg represents a *horizontal* surface, consequently the line fg is parallel to ab. The point g is then joined to the point d, and the back of the wing drawn in parallel to it, with the plan of the steps of the wing, as shown by the section of same.

* These values are only approximate, but quite enough so for practical purposes.

The width, *on the square*, between the abutments of an over bridge, or between the parapets of an under bridge, is regulated by the requirements of the Board of Trade, as mentioned hereafter. Four feet clear being required on each side of the railway, and six feet clear between the two roads, if the bridge be made for a double line.

The Irish guage is 5ft. 3in. clear between rails.

The rest of the drawing of this bridge is so simple as to require no explanation.

Curved parapets are not by any means universal: it is doubtful whether they are preferable, and are decidedly not so when carelessly executed; but I give the above as useful rules when they do occur.

When an under-bridge has inside spandril walls, they should be so spaced so to insure the rails being over the middle of two of them.

The colouring and printing put on a drawing are matters of taste, but as a general rule, neatness and *accuracy*, not ornament, should be aimed at.

On the *plan* of every bridge should be shown at least three views, one of the superstructure complete, one of the bridge, or part of it, with the parapets, string-course, coping of wings, and newel-caps removed, and a third of the foundations.

The dimensions of river bridges, at least as regards the span, will depend on the decision of the Drainage Commissioners. The engineer need not, however, delay the drawings and estimates until the certified schedule is furnished by the commissioners; he may design the river bridges of what he considers a sufficient size; and, should the commissioners direct larger structures, the alteration can be made. As a general rule, he should provide a water-way equal to that of the next bridge over the river *lower down;* but this rule is, of course, subject to circumstances, such, as the dis-

tance from the bridge being considerable, other streams joining the river between, etc.

The sizes of the culverts must be decided on similarly, the best guide being the size of the nearest culvert to the railway *down the stream.*

The portions of the masonry, or brickwork, which are represented *in section,* are usually coloured pink or blue. Masonry, *in elevation,* is not coloured on working drawings. Iron and timber are always coloured on a drawing; the former blue, or rather a neutral tint, and the latter with burnt sienna. In drawings of iron bridges, the wrought iron is usually represented by a much brighter tint than the cast iron, and the fact of any iron being *in section* is shown by lines drawn diagonally all over it. Timber in elevation is shown by plain sienna, and when *in section,* by the same crossed by diagonal lines of the same colour.

As many written dimensions should be shown on the drawing as will enable a mason to proceed with its construction, without reference to the scales, though the latter should never be omitted.

In case of any discrepancies, the *written* dimensions on the drawing are always held to be binding, though the scale may not agree with them, but are subject to any dimensions stated in the description of the bridge, embodied in the specification.

Iron bridges are either of cast or of wrought iron, the former being now confined to the cases of carrying roads over railways, where it is an object to save the height of the approaches, or for other reasons.

Wrought iron bridges to carry the railway over roads, are of two kinds, one where the railway is supported by under-girders, one under each rail, or by side and cross girders. The latter, if for double line, are of two kinds, firstly, with two side girders, with at least 25ft. 6in. clear space between

them, and carrying both roads, or a set of three girders with a single road between each pair.

These girders, in ordinary cases, are either lattice or plate girders, and may be in each case either single or box girders. The names explain their nature. The rules for finding the strength of each different part of a lattice, or plate girder, may be found in various works on the subject, such as E. Clarke's account of the Tubular Bridges; Latham's work on Lattice Bridges; Professor Rankin's Mechanics, and other books. In *The Engineer* of December 23, 1859, are given by Mr. B. Stoney, useful rules for the calculations of the different parts of a lattice girder.

When determining on the scantlings of iron in girders, the engineer must bear in mind the requirements of the Board of Trade, which are at present as given below, though subject at any time to alteration by the inspecting officers.

The regulations require that, in bridges of wrought iron, the greatest weight that can be brought upon it, added to the weight of the superstructure, shall not produce a greater strain on any part of the material than five tons per square inch.

In bridges of cast iron, the breaking weight should be equal to three times the weight of the bridge, added to six times the greatest load that can be brought upon it.

Without going deeply into the question of the strength of materials, I may here give a few rules for calculating the strength of iron girders.

The depth of a wrought iron girder should not be less than about one-fourteenth of the span, and the width not less than one-fortieth. Having settled on the depth, the next point is to determine on the area of the section of the flanges.

Taking W to be the weight of load bearing on the girder in question, uniformly distributed; l to be the length between

supports, d the depth, from centre of upper flange to centre of lower flange; a the area of lower flange, at the middle point of the girder; and s the strain per square inch which the engineer wishes not to exceed, a is given by the following equation:—

$$a = \frac{W\,l}{8\,s\,d}$$

W here must evidently consist of two parts, the first the greatest possible load, which may be taken at half-a-ton per foot-run of single line, and the second the weight of the girder. The latter is, of course, unknown, but must be roughly estimated before any calculations can be made. It is best taken from similar girders. In cases of small spans, it bears but a small proportion to load, and is therefore of small effect in the formula; but in larger spans, the areas of the different parts must be reëxamined with the true weight of the girder introduced instead of the approximate, and corrected, if necessary.

If the girder be rectangular in elevation, *i. e.* of constant depth, the area of the flange at any point, dividing the span into segments m and n, will be

$$\frac{4.a.m.n}{l^2}$$

If the depth be variable, the area of flange at any point will be $\frac{W.m.n.}{2.l.s.d.}$

The requisite strength to be given to the lattice-bars at any point of the beam, is given by

$$s.\mathrm{L} = 1{\cdot}4\left(\frac{w}{2} - \frac{w.m}{l}\right)$$

where L is the collected areas of the lattices intersected by a vertical section.

Theory would give a varying area everywhere along the flange, but practice requires the flanges to be composed of plates not exceeding certain lengths and of uniform thickness. The engineer should therefore take care that the area of any plate at its end *nearest to the centre of the bridge*, is sufficient; in which case the rest will, of course, but unavoidably, be more than sufficient. The junction of each pair of plates must, of course, be secured by covering plates as strong as the weaker of the two plates.

It is a curious fact that rivets require the same force to cut them across at right angles to their axis (as happens when a junction fails by shearing the rivets), as it does to rupture a rod of the same section by tension.* Hence comes the following rule:—

> *The number of rivets to secure a joint plate on each side of the joint should be equal to the area of section of the weaker plate, divided by the section of rod used for the rivets.*

The position of the rivets for covering plates should be accurately shown, as well as the length of the plate, as otherwise the contractor might crowd the requisite number of rivets into a smaller covering-plate, and thus weaken the plates.

Theory also would give a different section for each lattice-bar, and even for each part of a lattice-bar; but practice requires that alterations be made, like in the case of the plates, by groups. The lattices that incline from the bottom up, and at the same time away from the centre, are all in a state of tension, while the others are all in compression.

The tension lattices are always plain bars, generally of

* In fact no matter how the iron be broken, whether by shearing, punching, or direct tension, the breaking force bears the same proportion to the *superficies* of the ruptured surface.

uniform thickness, and of widths varying by half inches, the positions of the changes being determined by the formula.

The compression lattices are of various forms, such as angle, T, and ⊔ or channel iron, the form and sections to be determined by the engineer.

The tension-bars, from being in this state, are not liable to any displacement in form; but the compression-bars are liable to buckling, hence the necessity for the other forms of iron. In box-lattice girders, the opposite compression-bars, near the end of the girder, are often connected by lattices or cross-bars, thus stiffening the girder greatly against side motion.

For further information, I must refer the reader to books specially written on the subject of iron work, where he will find rules, etc., that will enable him to investigate the most complicated cases.

The number of copies of each drawing required are four, one for the contract deed, one for the engineer's office, one for the resident engineer, and one for the contractor; the last two are usually made on tracing paper.

No drawing or tracing should ever be allowed to leave an office without the proper scales being shown on them.

In the case of a skew bridge, the elevation of the arch is elliptical.

If the arch be a semi-ellipse, the elevation will also be a semi-ellipse, but with a major axis equal to the span on square, multiplied by the cosecant of the angle of skew.

If the arch be a circular segment, then the elevation will be an elliptical segment.

To draw this, the rise and major axis of the complete semi-ellipse corresponding to the semicircle of which the arch is a segment, must be drawn, and the segment then marked.

The different methods of drawing ellipses will be found in any book on drawing.

SPECIFICATION.

Engineers in large practice have usually specifications in printed forms, with blanks to be filled up for each particular railway.

It is not within the compass of this work to enter into the question of the general specification, which would take a book to itself.

In the middle of the general specification are inserted descriptions of the bridges.

The description of a bridge should give the name of the bridge, the number of its drawing, and the purpose for which it is intended. It should also specify of what class of masonry, as described in the general specification, each part of the bridge is to be. If the superstructure be of iron, the description should fully show the scantling and kind of iron of each part, whether angle iron, plate, T iron, rivets, etc.

This "description" of a bridge overrides the drawing, so that the greatest care should be taken to make it correct.

As an example, I give the description of the bridge of which Plate 3 is a drawing:—

"DESCRIPTION OF BRIDGE No. 7.

"*Ballygriffin Public Road Bridge.*

"This bridge is intended to carry the public road over the railway at an angle of skew of 60°, and is to be of the form and dimensions shown on drawing No. 7.

"The excavation for foundations is to be carried to the depth shown on the drawing, or such other depth as the resident engineer may require.

"The foundations are to be of rubble masonry, as described in clause No. 1, under the head 'stone masonry'.

"The backing of abutments and of wings, the counterforts, haunching, spandrils, and newels, are to be of rubble masonry, as in clause No. 2.

"The face-work of abutments, wings (to a depth of two feet below slope line), newels, and spandrils is to be as in clause No. 5.

"The parapets, and returns of parapets, are to be as in clause No. 6.

"The string-course is to be of second class dressed work, as in clause No. 9.

"The coping of parapets, coping of wings, and newel caps are to be of first-class dressed work as in clause No. 8.

"The arch-sheeting and springers of arch-sheeting are to be as in clause No. 12.

"The ringpens are to be as in clause No. 11.

"The approaches to this bridge are to be raised 18 feet, and formed, fenced, and metalled, in strict conformity with drawings Nos. 17 and 18,* and with the directions given under the head 'Diversion and alteration of roads', in the general specification".

General clauses with reference to time, method of payment, delivery of any materials provided by the company, and other matters, constitute the rest of the specification.

In most cases the materials for the permanent way are provided by the company, but sometimes the contract includes the provision, as well as laying of the permanent way.

The blanks referred to above, to be filled up, are principally the following:—

The description of the commencement and end of the work. This should be very precise, giving the numbers of the pegs as shown on the section, the number of the fields as referred to the parliamentary plans, and the names of the townlands, parishes, and counties.

The ratio of slopes of the cuttings and embankments,—

* One of these is the drawing of road sections, the other the drawing of general cross-sections of road approaches.

In Ireland clay cuttings are usually taken out at slopes of $1\frac{1}{2}$ horizontal to 1 perpendicular, and rock at $\frac{1}{4}$ or $\frac{1}{2}$ to 1. A slope of $1\frac{1}{2}$ to 1 is quite sufficient for gravel, sand, and ordinary clay, but few cases occurring where a greater slope is required. The slope of rock cuttings depends on the nature of the rock, *and on the dip, if the rock be stratified.* If the dip be in the direction, or nearly so, of the line of railway, the slope may be as stiff as the material will admit of, but if the dip be at right angles, the slope, on one side at least, must be increased.

The widths of bases of cuttings and embankments:—

Clay cuttings are made with a base of either 16 or 18 feet, according to the judgment of the engineer-in-chief. Cuttings in rock should not be made with a less base than 15 feet. Embankments are usually made with a top of 18 feet.

This is for a single line. If the line be intended to be double, 12 feet more should be added to the widths of cuttings and embankments.

The rest of the blanks to be filled, are principally numbers of drawings, places where materials are to be deposited, and the time by which the work is to be finished.

THE ESTIMATE.

The different items which compose an estimate *of works* are as follows:—

Trimming, soiling, and sowing slopes.

Excavation in clay.

Excavation in rock.

Excavation of side-cutting.

Excavation in diversions of rivers and streams.

Excavation in approaches and diversions of roads.

Excavation of side cutting for forming embanked road approaches or diversions.

Embanked road approaches or diversions formed from railway cuttings.

Ditch and mound fencing with wire paling.

Dry stone wall fences.

Road metalling and pitching.

Ballast.

Boxing.

Laying permanent way.

Public road level crossings.

Tunnels.

Culverts (mentioning the different sizes).

Bridges, No. 1.

" No. 2, etc.

Maintenance of way.

The first operation is the calculation of the quantity of excavation in the railway cuttings, both of clay and rock.

I will suppose that the office is provided with a copy of Sir John Macneill's earthwork tables, and that the base and slopes adopted by the engineer are among those given in that book.

Sheets of paper are ruled in the same way as shown in Plate 4, or similarly, and the engineer proceeds to fill up the columns as shown.

In the first column he enters the number of the cutting or embankment; in the next, the number of the peg, or peg and decimal of a chain, at which the surface of the ground varies from a straight line; in the next, the difference between every pair in the last column—*i.e.* the length of each block, writing the numbers in the second column *between* the ruled lines, and the numbers in the third column *on* the lines.

In the fourth or fifth column he next inserts the height of embankment, or depth of cutting, as the case may be.

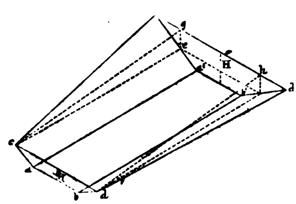
It is the best plan to fill up these columns for the entire length of the line, or of a division thereof, before proceeding to the next step, which is to take out from the table and insert in the sixth column the tabular number belonging to each pair of heights. This also had better be done on all the sheets at once.

The tabular numbers are then multiplied by the corresponding lengths which have been entered in the third column, and the result entered in the seventh column, headed "Products". The "products" of each cutting or embankment are then added up, and the result entered in its proper column.

The form of these papers may be changed as each engineer thinks well; but the one form only should be used in any one office.

The numbers given in the tables are arrived at in the following manner:—

Fig. 10.



Let *abcd a′b′c′d′* represent the block of a cutting, which has for its heights H and H′, for its base *ab* or *a′b′*, which I will call B, for its length *aa′*, which I will call L, and for its ratio of slopes the ratio R.

Let the dotted lines *ce* and *df* be drawn parallel to *aa′*, and the other lines as shown.

The content Q is evidently equal to the sum of the contents of the figures *abcd a′b′ef*, *cdefgh*, and twice the content of the figure *cc′eg*, that is equal to

$$L(BH+H^2R)+L(B+2HR)\left(\frac{H'-H}{2}\right)$$

$$+\frac{2L}{3}\left(\frac{H'-H}{2}\right)(H'R-HR)$$

$$=L\left\{\frac{B(H+H')}{2}+R\left(H^2+HH'-H^2+\tfrac{1}{3}(H'-H)^2\right)\right.$$

$$=L\left\{\frac{B(H+H')}{2}+\frac{R}{3}(H^2+H'^2+HH')\right\}$$

This is known by the name of "the Prismoidal Formula". All these, it must be remembered, are in the same units, and if it be wished to express Q in cubic yards and L in feet, the expression becomes

$$L\left\{\frac{B(H+H')}{54}+\frac{R}{81}(H^2+H'^2+HH')\right\}$$

The part within brackets is the tabular number of the first set of tables, and the two parts of it are the separate numbers under the heights H and H′ in the table to base 1 and slopes of R.

There are two approximative methods of ascertaining the content of a prismoidal block; the first, or method of mean heights, by taking it as if the section in the middle were the average section; and the second, or method of mean areas, by taking half the sum of the end areas to be the average section.

The errors belonging to each of these methods are seen at once, by comparing the content as given by it, with the true quantity.

The method of mean heights gives a content of

$$L\left\{B\,\frac{H+H'}{2}+\left\{\frac{H+H'}{2}\right\}^2 R\right\}\text{ and an error of }-\frac{(H-H')^2}{12}$$

The method of mean areas gives a content of

$$L\left\{B\,\frac{H+H'}{2}+\frac{H^2+H'^2}{2}\,R\right\}\text{ and an error}$$

$$\text{of} + \frac{(H-H')^2}{6}$$

So that one method gives an error in excess, the other an error on the other side, and one error is double the amount of the other.

There is another way of expressing the *true* content; it is: To the sum of the end areas, add four times the middle area, and multiply the sum by one-sixth of the length.

In cuttings it will constantly occur that the contents are not, as I have above supposed, all rock or all clay, but will be partly rock and partly clay. In this case the rock can be taken out as above, and the clay taken out in blocks the same way as before, with this exception, that each block will have a different base. The base of each block of clay cutting must be taken as a mean of the bases at each end, or, what is the same thing, a mean of the widths of the top of the rock cutting at those points.

This method of getting the quantity of the clay is not strictly accurate; the true content of a block of this kind is given by this formula

$$Q = L\left(\frac{B(2H+H')+B'(2H'+H)}{6} + \frac{R}{3}(H^2+H'^2+HH')\right)$$

where B is the base of clay at the end at which H in the height, and B′ the base, and H′ the height at the other.

The error introduced by the approximative method is

$$+\frac{(B-B')\,(H-H')}{12}L$$

It is to be remarked that this error is to some extent compensating, sometimes being in excess, and sometimes the other way. The approximative method gives too much, if at the same time $B > B'$ and $H > H'$ and too little if $B > B'$ and $H < H'$.

There would be little difficulty in taking it out correctly, if tables were constructed for the purpose.

Again, cases will occur where none of the rules above given apply, namely, where the ground is so uneven as to require cross-sections.

The best thing to be done in this case is to take the mean of the two areas of the two cross-sections, and multiply it by the length between them, and reduce to yards.

Or they may be treated in such a way so as to introduce them into the regular earthwork sheets, by drawing an equating horizontal line on the cross-section, and entering the scaled height of such line in the regular columns of heights.

The earthwork having been calculated, the next thing is to take out the number of superficial yards of soiling required,

Referring to the Figure in page 84, it will be seen at once that the soiling for that block is equal to twice the area $bd.\,b'd'$.

$$bd = \sqrt{H^2 + H^2R^2} \quad = H\sqrt{1+R^2}$$

$$\therefore \text{ area of } bdb'd' \quad = L.\frac{H+H'}{2}.\sqrt{1+R^2}$$

$$\text{and the whole soiling} = L.\sqrt{1+R^2}.\,(H+H')$$

In the usual case of clay cuttings (of course no soiling is required in rock cuttings), the ratio of slopes $R = \frac{3}{2}$, and consequently

soiling $= L.\,(H+H').\times \cdot 2$, where L, H, and H′ are in feet, and the results in super yards.

Hence the way to fill up the last column on the paper is to multiply each pair of heights by one-fifth of the corresponding distance.

For other slopes the best (*i.e.* quickest) way is to multiply each pair of heights by the distance, and the sum of these products by the number $\sqrt{1+R^2}$.

The quantities should next be collected in an abstract table, and the total quantities made out.

The next item, side-cutting, must be deferred until the earthwork in river diversions, road diversions, and in road approaches, has been calculated.

The excavation in diversions of rivers and streams is taken out in the same way as the cuttings.

Embanked road approaches are taken out similarly to embankments, with a base equal to the width of the road, with the width of two walls and an offset for stability on each side. Three feet six inches on each side, in addition to the width of the road, gives a sufficient base for dry stone wall fencing. Of course, if wooden paling be intended, the width will be greatly reduced.

Excavation of road approaches is usually taken out with dwarf walls, which serve as the road fences; in this case the excavation consists of two items, the lower being a plain block with vertical sides, and the upper a prismoidal solid with a base equal to the width between the top of the two dwarf walls.

When he has marked all these earthwork quantities, both of filling and excavation, in their proper places on the office copy of the section, the engineer proceeds to *distribute* the earthwork, or in other words, to find out what side-cutting is required for railway embankments, and what for embanked road approaches.

The excess of the total quantity of embankment over the total quantity of excavation will by no means give the side-cutting. Cases have occurred where the quantity of cutting has been greatly in excess of the quantity of the embankments, and a considerable quantity of side-cutting required, and yet the most economical gradients were made use of.

The quantity of excavation in river diversions can be taken

as forming part of a neighbouring embankment, without any extra charge, and also road excavations, if situated close to the embankment.

When a cutting over which a road is passed by an embanked approach, is insufficient to make up the neighbouring embankment, it depends on the prices at which the engineer is directed to calculate the estimate, whether it is more economical to make up the embanked road approach from the railway cutting or not.

For instance, if the price of side cutting to embanked road approaches be 10d., and to railway embankments be 8d., and the additional price of shifting earth from a railway cutting to a road approach be 3d. per cubic yard, it will be evidently more economical to make up this road approach altogether from side cutting, and let the whole of the cutting go to form the embankment.

If the cutting is more than sufficient to form the railway embankment, but not sufficient to form both it and the approach, it would, at the above prices, be best to put down the difference as side cutting to the approach; while, had the price for side cutting to the railway embankment been only 6d., it would have been more economical to form the whole approach from the cutting, and throw the deficiency on the embankment.

There is a length of lead which cannot in practice be exceeded, and which causes the anomaly of a cutting being run to spoil at the same time that side cutting is provided for an embankment. This length of lead depends generally on the average price at which the earthwork is to be put in the estimate, and on the gradients. This is not reducible to figures, but must remain a matter of judgment.

The next item is fencing. The fencing of the railway may fairly be taken to be continuous along both sides of the line,

without any deductions for bridges, level crossings, or culverts. The lines of fencing are not parallel to the line of rails, and, if perfectly continuous, would necessarily, owing to the variable width of the railway land, be longer than the centre line; and this, coupled with the trouble and expense of temporary fences at the gaps, accounts for the above being fair measurement.

No allowance is or ought to be made for additional length caused by undulations of the surface; because the specified section of the mound or wall is measured on a *vertical* section, and consequently the measurement should be taken horizontally. Fencing is always measured in lineal yards.

Next comes road metalling and pitching. It is usual to measure these two together, and put them at an average price per cubic yard.

Ballast and boxing may be estimated either separately or together; the former is the more usual practice, but I think the latter preferable, as it facilitates the settling, in case of a contract being surrendered before it is completed. Both are measured in cubic yards, being together usually about 2 or $2\frac{1}{6}$ cubic yards per yard run of single line.

Laying permanent way is measured by the yard run of line, single or double, as the case may be. Neither ballast, nor laying way, include anything in the way of sidings, which are afterwards to be paid for extra.

Laying crossings and points are paid for at a price per lineal yard additional to the laying of same as permanent way, and always form an extra, as the amount required cannot be told until the contract is finished.

Culverts are classed according to their different spans, as 12 ft., 10 ft., etc., the 24 in. and smaller being usually called drains.

Culverts are usually measured on the arch-stones only,

that is, from ring to ring; no allowance being made at all for the wings or excavation. This is not an universal rule, sometimes one wing is measured in.

Until the Drainage Commissioners have furnished their schedule of culverts, the exact depth or size of each, and consequently its length, cannot be determined; but as the usual custom is to place the invert five feet below the surface of ground, the estimate is made on this rule.

Taking, then, five feet from the height between invert and top of culvert, and deducting the difference from the height of the embankment, the height of filling over the culvert is got. This height multiplied by twice the ratio of slopes and added to the width of formation, gives the length of each culvert in feet, if square to the line of railway.

If formation be 18 feet wide and the ratio of slopes $1\frac{1}{2}$ to 1, six added to the last-mentioned height gives the length of the culvert at once in *yards*.

If the culvert be a small one, and shown by the drawing to run to the outside of the fences, the above rule does not apply, and the culvert length should be taken from the plan.

The bridges are next given in order, the bulk price of each being given.

Each bridge estimate comprises the following:—

Excavation.
Rubble masonry in foundations.
Rubble masonry elsewhere.
Hammer-faced or hammer-squared work in facing.
Hammer-faced or hammer-squared work with two faces.
Rock-faced quoins.
Dressed work.
Arch sheeting.
Puddle.

And if any occurs,

Iron, wrought.
Iron, cast.
Timber.
Brickwork.

Excavation. The excavation consists of that required for the different foundations.

If the bridge be over the railway, and for a double line, while the line itself is single, the excavation for the double line forms another item of the excavation. It is usual to widen the single line gradually for 100 feet when coming to the bridge, so that the excavation for the double line will be

$$100'{\cdot}0'' \times d \times h.$$

Where d is the difference in width of the single and double line, usually 12 feet, and h the height of the cutting.

In taking out the measurements for excavation, it would be unfair to take neat measurements; earth cannot be taken out plumb, therefore some allowance should be made. This is best done by adding one-fourth of the height of the excavation to the width at bottom, which allows for a slope of $\frac{1}{4}$ to 1.

For instance, if the excavation for an abutment be sixty feet long, six feet wide at the bottom, and four feet deep, it would be entered on the estimate sheet as

$$60{\cdot}0 \times 7{\cdot}0 \times 4{\cdot}0.$$

With regard to the order in which these numbers should be entered, it should be made a fixed rule, that the first measurement should be in the direction of the centre line of bridge, the second in the direction at right angles to the last, and the third vertically; this is important, as it guides the engineer who checks the estimate, and thus saves *time*.

The next item is *rubble masonry in foundations.*

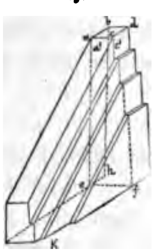
The quantity is given by the product of the length, width, and height: it must be remembered in the case of skew bridges, that either the length or width must

be measured on the square, and the other on the skew. If any small reëntrances occur in foundation work they are usually neglected, and the work measured full. Rubble masonry in foundations is usually put at a slightly lower price than other masonry, not that inferior work is to be allowed, but because several incidental expenses, such as for scaffolding, etc., are not incurred.

Rubble masonry above foundations.

The measurements of the abutments, the counterforts, haunching, and spandrils, present no difficulty. If the wings are straight back, the measurement is similarly easy; but some difficulty occurs about the measurement of splayed wings. An example will, perhaps, best show the way of estimating splayed wings.

Fig. 11.



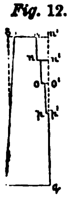
The figure shows a splayed wing completely separated from the bridge; it is designed for a returned parapet, as in Plate 3.

The next figure shows the section of the same wing. The first part taken is that which forms the return, *a b c d e f g h;* the measurements of this are

$cd \times$ the mean width $\times$ the height.

The mean width is equal to

Fig. 12.



$$rm' + rs - \frac{mm', m'n' + nn', n'o' + oo', o'p'}{m'q}$$

The sloping blocks from each step up are then to be taken separately, the measurements being the mean length measured on the line fk, the mean width (as $a'c'$), and the height (as mn). It will be seen that this is only approximative for all the blocks below the top one.

Hammered work in facing.

This is superficial measurement. The abutments, wings, and outside spandrils are usually hammer-faced. If the wings are straight back, the hammer-facing extends only to a certain distance below the slope line of the earth; this depth will be found in the "description" of the bridge. By some the hammer-facing is measured cubically, and estimated at a certain depth into the work; of course this must in that case be deducted from the measurement of rubble masonry above.

In the practice of Royal Engineers the hammer-squaring is not measured at all, but a proportionate additional price put on all the rubble masonry.

Hammered work with two faces.

This is in parapets. The measurements are evident. In this case, and wherever they occur, when ashlar quoins are specified, the quantity in the quoins must be deducted from the other work.

Rock-faced quoins (if any).

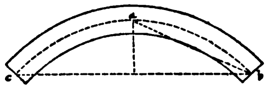
These are the quoins of the abutments, newels, and parapets. If the wings be straight back, the ashlar quoins of the pilasters (which usually terminate the wings) do not go down the whole depth of the wing, but only to a certain depth below the slope of the embankment, usually to the same depth as the hammer-facing is carried, as mentioned above.

Dressed work, first class.

This includes all coping, caps, block-in-course, and ringpens. The coping and caps generally have some chamfer or moulding; this is not taken into account, and the stones are measured full. The measurements for the ringpens are mean width × length × height.

The mean width is given by the specification.

Fig. 13.



The height is given on the drawing, and the length is obtained in this way. Midway between the intrados and extrados draw the dotted line *b a c*, which is the length of the ringpens. This arc is equal to

$$\frac{8ab - bc}{3}*$$

In case of a skew-bridge, the length must be got by measuring on the elevation, as the depth given by the specification is measured on the coursing spirals or square to the face line of arch.

Dressed work, second class.

This includes stringcourse and impost. The dressed work is not always divided thus into two *classes*, but invariably some distinction in price is made; the reason for this being that coping, etc., has so much more surface *dressed* than stringcourse.

Arch sheeting.

The length is the same as for the ringpens, the height as shown on drawing, and the depth the width of the bridge on the square, deducting the depths of the two courses of ringpens. If there is no impost course the top stones of the face of the abutment should be measured and put at the same price as arch sheeting and ringpens respectively under the name of "springers".

Arch sheeting may be of two kinds, corresponding to random and coursed masonry, and the latter again may be of two kinds, *guaged* and *broken*.

The best of all is guaged sheeting, in which every stone

* For demonstration, see article "Mensuration", *Encyc. Brit.*, seventh edition.

is the same thickness as the ringpens, and the courses forming fair straight lines from face to face if the bridge be square, or fair spiral lines, if skew.

The next best is where the sheeting is in courses, but each course containing more than one stone in thickness. Courses, in this class, should finish in a ringpen or ringpens exactly. Lastly, the sheeting may be all random work. If random work be used in skew arches, the stones *must* be dressed according to Buck's method; the other plans, such as Harte's, not applying except to guaged sheeting.

Puddle. The measurements are evident.

The measurements are all entered on the estimate sheet in feet and inches, and are then multiplied together and entered in a column ruled for the purpose. The whole quantity of each description of work is then added up and reduced and entered in the next column in the units by which the price is taken. Thus excavation, rubble masonry, brick work, hammer-faced work in parapets, arch sheeting, and puddle are paid for by the cubic yard. Hammered work in facing is paid for by the superficial yard, dressed work, ashlar quoins, and timber by the cubic foot. In reducing, to cubic yards for instance, the division may leave a remainder, in this case the nearest unit should be taken.

In measuring timber work in bridges the timbers should be measured to the end of the tenons, and, if cut off at an angle, on the greatest length.

The measurements of the masonry are simple, and will be learned sooner by going over an estimate with the drawing than by any description. In measuring iron work, great use may be made of a small book, called *Penn's Tables*, which gives the weight per foot, super or run, as the case may be, of iron of all scantlings, both wrought and cast. Where the

tables are not handy, the weights may always be found by the rule given in *Clarke's Description of the Tubular Bridges*, viz.,

> *The weight in lbs. of any uniform bar of wrought iron per yard run is equal to ten times the number of square inches in its section.*

Thus not only do we know that a bar of wrought iron, one inch square, weighs 3·33 lbs. per foot run, but also that quarter inch boiler plate weighs 10 lbs. per super. foot.

For cast iron, one twentieth of the whole, as given by the above rule, should be deducted.

In measuring iron, the portion of a rivet embedded in the plates is measured in the plates; and in addition three times the diameter in length is allowed for the two heads.

The maintenance of way is generally supposed to be for one year, and either given as a lump sum, or as so many miles, at a sum per mile.

END OF PART II.

APPENDICES.

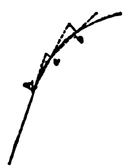
A.

LAYING OUT CURVES.

Though I think that the method known as Mr. Rankine's is decidedly the best *and surest* for laying out curves in the field, I give here a description of two other ways of marking in the curve.

Method by offsets.

Fig. 14.



When the springing points of the curve have been fixed, the curve may be marked in thus:—The chain is to be stretched out from A in the direction of the tangent, and an offset laid off at right angles by which the point *a* is found. The chain is then stretched from *a* in the direction A*a* produced, and a pin put in. A short rod of a calculated length is then put against the pin and the end of the chain and the other end of the rod held together. Being held thus when the chain is taut, the end of the rod is at a point, *b*, in the curve. This process is repeated until the second springing is reached or passed. This method is very handy when the ground is *very* level, and free from fences; and is of the greatest use in putting in pegs on formation level for the laying of the permanent way. It is also very useful for marking out road approaches, and road diversions, with regular curves.

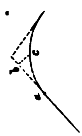
The first offset is equal to half the length of the rod. The length of the offset rod is $\frac{\text{chord}^2}{\text{radius}}$.

By this means S curves, or curves with a change of radius, can be put in, *provided* that the alteration be at one of the pins by which the curve is marked.

The offset at such a point of change is equal to the half sum of the offsets of the two curves, if the new curve be of the same sign; and equal to the half difference of same, if the new curve be in the opposite direction.

Apart from the difficulty of using this method accurately in very rough ground, it is open to the objection that the pins cannot represent the regular 100 feet pegs, which must be put in afterwards. The offset belonging to two chords of unequal length cannot be calculated, except with great labour; and consequently the 100 feet pegs cannot be put in at first by this method, except the springing occurs *at a peg*.

Fig. 15.



The second method is by tangents, *i. e.*, chaining along the tangents, and laying off rectangular offsets of calculated lengths. The length of any such offset, bc, is equal to radius $-\sqrt{(\text{radius})^2 - ab^2}$.

This method may be used on very rough ground; and, indeed, may occasionally be used where Rankine's method is inapplicable; as, for instance, in laying out a curve round a bluff precipice, with low lands, where the tangents can be laid out. However, it is open to the same objection as the method by offsets with respect to the distances of the pegs.

On the whole, I have no doubt whatever that in Irish practice, where the pegging is finished before the survey, Rankine's method is by far the best. The reader will find the method by offsets well described in a paper by Mr. Bourne in the Transactions of the Institution of Civil Engineers.

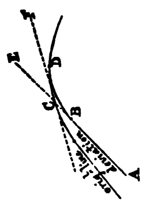
B.

DEVIATIONS.

Sometimes after the line has been pegged, a deviation of part may be required.

In pegging such a deviation there is no difficulty about the starting, or about the joining in at the end, provided that at the latter point the original line was straight. If, however, the original line be curved at that point, the following case arises.

Fig. 16.



The deviation AB is being pegged; required the distance BC by which the springing B may be found, so as to start the curve BD, which shall join in properly to the original curve.

Let the radius of the curve BD be r, and the radius of the old curve R.

The angle ECF must first be observed, which can be done without difficulty, let it be called θ then

$$CB = R \sin \theta - (R - r) \sin \theta',$$

where θ' is found from

$$\cos \theta' = \frac{R \cos \theta - r}{R - r}.$$

C.

REQUIREMENTS OF INSPECTING OFFICER OF THE BOARD OF TRADE.

Though the Inspecting Officer does not make his appearance until the very last stage of the Resident Engineer's work, still the requirements so far affect the designs and work generally that some notice of them here will be useful. They are not fixed, but I give the latest which I have seen, dated July, 1861.

The requirements are:—

1. Platforms to be not less than six feet wide. The descent at the end to be by ramps, not steps. No fixture to be nearer to the edge of the platform than six feet.
2. A Clock to be provided at each station.
3. Signal and distant signal to be provided at each station.
4. Regulates position of switch handles.
5. No facing-points, except at junctions or on single lines, or in *exceptional cases.*
6. Sidings to be provided with locked chockblocks, and

if falling towards the line, with a blind siding, and points closed against the main line.

7. Turntables to be erected where engines require to be turned.
8. For every *cast* iron bridge, the breaking weight shall equal three times the permanent load due to the weight of the superstructure, added to six times the greatest moving load that can be brought on it.
9. For every *wrought* iron bridge, the greatest load which can be brought on it, added to the weight of the superstructure, shall not produce a greater strain on any part of the material than five tons per sq. in. The heaviest engines in use on the railway afford a measure of the greatest moving weight to which the bridge can be subjected. (See page 76).
10. The upper surfaces of *wooden* bridges and platforms should be protected from fire.
11. The joints of the rails should be secured by means of fish-plates or other secure fastening.
12. The chairs on all curves should be secured with iron spikes. With "*contractors*" or with bridge-rails, a fang bolt should be used at the joints, at least.

"Contractors" rails are rails of a peculiar form, requiring no chair; they may be seen on the Midland Great Western Railway (Ireland).

13. On Irish railways, no standing work should be nearer to the rail than four feet.

This regulates the width between the abutments of an over-bridge, and between the parapets of an under-bridge.

14. The width between the lines of rails, or between a line of rails and a siding, shall not be less than six feet.

This affects the dimensions of works for a double line, or about a station.

15. If a viaduct occurs near a station, a parapet wall, three feet high, with a railing on top, must be erected. For the protection of the plate layers, viaducts under the railway should be guarded by

a hand-rail, and if of timber or iron, should have man-holes, to facilitate inspection.

All depends on what sized bridge the inspector may consider a viaduct to be.

16. At all level crossings of turnpike and public roads, the gates must be made so as to close across the railway as well as across the road. There must also be a box or lodge for the gatekeeper.
17. The gates of public road level crossings must have signals visible from the line, and distant signals, if required.

The necessity for distant signals will depend on the distance at which the gates can be seen, and on the gradients approaching the gates.

18. At all junctions main signals and distant signals for each line are required; and clocks should be placed in a conspicuous place for the use of the signalmen.
19. It is desirable that the signal handles and levers of the switches at junctions should be brought together upon a properly constructed stage. They should be so arranged that a signalman shall be unable to lower a signal for the approach of a train until after he has set the points in the proper direction for it to pass; and that it shall not be possible for him to exhibit at the same moment any two signals that can lead to a collision between two trains.
20. Mile posts and gradient boards should be provided along the line.
21. The junctions between main line and sidings to ballast-pits, quarries, or collieries, should be protected by a distant signal in each direction.

D.

THE TRAMWAYS' ACTS.

Though they are not directly connected with the construction of a railway, I insert here abstracts of the two Tramways' Acts, as it may be convenient to have them to refer to.

The first Act was passed in 1860, and provided that a company of promoters should have the power of constructing a tramway, and of purchasing land for the same, compulsorily, provided that they complied with certain regulations corresponding to "standing orders", and succeeded in obtaining certain sanctions corresponding to the passing of a Bill by Committees of the Houses of Parliament.

THE TRAMWAYS (*Ireland*) ACT, 1860.

23 *and* 24 *Vic., c.* 152.

AN ACT TO FACILITATE INTERNAL COMMUNICATION IN IRELAND BY MEANS OF TRAMROADS OR TRAMWAYS.

CLAUSE I. requires the promoters to give notice, by advertisement, in the months of April and May, or either of them, preceding their application, of their intention of so doing.

The engineer's business is to furnish the solicitors of the promoters with a correct list of the townlands, parishes, and counties through which the proposed tramway is to pass, and also a careful description of each of the termini.

This clause is modified by the Act of 1861, in respect of the dates of the advertisements only.

CLAUSE II. requires that on or before the first day of May, the promoters shall deposit with the secretary of the Grand Jury of any county within which the tramway is proposed to be made.

1. A copy of the advertisement.
2. A published map.
3. A plan, book of reference and section; and with the County Surveyor and Clerk of each

Union, through which the tramway is to pass, a copy of the same documents.

The forms in which these documents are to be prepared is given in an Appendix, which is an exact transcript, *mutatis mutandis*, of the "standing orders", Nos. 43, 45, 46, 47, 48, 50, 51, 52, 53, 54, and 55, *but with this important addition, that every plan and section must be signed by the engineer to the promoters.*

Everything mentioned in the early part of this book with reference to preparing work in accordance with "standing orders" will apply in the case of a tramway application.

The limits of deviation must be in accordance with CLAUSES Nos. XLII. and XLIII.

The scales of general and of enlarged plans, of sections and cross sections are the same as for a railway plan—in fact, the plans and sections require exactly the same work and precautions as parliamentary plans and sections of a railway.

In fact, as will be seen, there are more opportunities afforded of opposing a tramway application than there are of opposing a private bill.

This clause is modified by the Act of 1861, in respect of the date of lodgment only.

It is also affected by CLAUSE VI. of this Act.

CLAUSE III. requires the promoters to give notice to all persons legally interested in any lands affected by the tramway, on or before the 2nd day of May.

These notices, *and the engineer's work in connection with them*, are exactly similar to the notices for a railway (*vide* p. 21).

This clause is modified by the Act of 1861, in respect of date of notice only.

CLAUSE IV. requires that, on or before the 12th day of May, the promoters must deposit with the Secretary of the Grand Jury, and with the County Surveyor—

1. A memorial asking for an order in council authorising the tramway.
2. An estimate of expense.
3. A list of persons interested.

The engineer is concerned only with the estimate. No

form is prescribed, the usual one for railways given at page 25 will answer.

This clause is modified by the Act of 1861, in respect to date of lodgment only.

CLAUSE V. directs the Grand Jury to inquire into the compliance of the promoters with the requirements of the previous clauses, and to hear opposition.

After this it directs the Grand Jury to inquire into the *merits* of the undertaking, taking into consideration the report of the County Surveyor, and any properly qualified opposition. The Grand Jury must then approve, or disapprove, *provisionally*, of the scheme. If the application be approved of, an appeal may be made by the opposition to the Lord Lieutenant in Council.

This is altered by the Act of 1861, in so far as the *provisional* nature of the approval or disapproval is done away with, and the approval or disapproval made absolute (*vide* Clause X. *infra*).

CLAUSE VI. gives the engineer leave, when the work lies in more counties than one, to lodge with any officer only as much as belongs to the *county* concerned.

There is a difference here between the case of a tramway and of a railway. By "standing orders" the engineer is required to lodge with the Clerk of the Peace the whole set of plans, even when the work lies in more counties than one, but with the Clerk of an *Union* only so much as lies in that *Union*. The Tramways' Act requires, on the contrary, the engineer to lodge with the county officers only so much as lies in the *County;* and, at the same time, with the Clerk of an *Union* as much as lies in his *County*.

CLAUSE VII. enables the promoters, where the scheme affects two counties, to appeal against the disapproval of one Grand Jury, if the application has been approved of by the other.

CLAUSE IX. requires the promoters, in case their application be approved of, to deposit with the Board of Works duplicates of all documents and plans mentioned before, as soon as may be after the

approval of the Grand Jury. The Board of Works shall then appoint an officer or officers to inquire and report on the scheme, with any modification in an engineering or other respect that may seem to them advisable.

A schedule annexed to the Act gives the heads of inquiry by the Board of Works.

1. The financial arrangements.
2. Share list, capital, loans, etc.
3. Sufficiency of the estimate.
4. The merits in an engineering point of view; the character of the gradients and curves; the number and extent of the tunnels, if any; public road level crossings, if any; and any peculiar engineering difficulties, and the method of overcoming them.

By the Act of 1861, *the inquiry by the Board of Works is restricted to the fourth head.*

The Board of Works on this inquiry shall hear all properly qualified opposition, and can call for all documents or evidence required.

This clause is so far altered by the Act of 1861, that the report of the Board of Works must be made before any investigation by the Grand Jury.

CLAUSE X. requires the Grand Jury, at the next spring assizes, to ratify the approval of the previous one, taking into consideration the report of the Board of Works, and a further report of the County Surveyor.

This second inquiry by the Grand Jury is abolished by the Act of 1861.

CLAUSE XIII. enables the Lord Lieutenant in Council, when any tramway has been approved of as above, to make an order in Council authorizing the making of the works.

CLAUSE XIV. requires the Lord Lieutenant to take steps as soon as may be after the order, to have such order confirmed by an Act of Parliament, *and that until such act be obtained, the order shall have no effect.*

The latter half of this clause is repealed by the act of 1861.

CLAUSE XXI. requires the promoters, in case of any altera-

tion from the original plan having been introduced in the Order in Council, to lodge plans, sections, and all other documents as before, and also with the Board of Works, before commencing work.

CLAUSE XXII. requires estimates, draft award, and copies of same, to be lodged in the same manner as the documents before referred to.

These estimates and awards are to be in accordance with the Land Clauses Act, 1851, excepting that no plans, sections, or books of reference need be lodged more than once.

CLAUSE XXIV. limits the traction power to animals. It also requires the trams to be of iron, and laid to 5ft. 3in. guage.

CLAUSE XXXIII. is the next one which concerns the engineer. It gives him power, with the permission of a justice of the peace, who is not interested in the tramway, to enter on any lands such as are liable to be taken for the purposes of the tramway.

This gives the engineer facilities which he has not in preparing *railway* parliamentary plans; he does not get this, or a similar power of entry, until after the act is obtained.

CLAUSE XXXIX. requires the promoters to obtain the consent of two-thirds of the owners of houses adjoining any street before altering its level, and limits such alteration to 4 feet. It also requires the street if altered to be so for its full width, except it is otherwise desired by the Board of Works.

CLAUSE XLI. requires the promoters to deposit with the Board of Admiralty a copy of so much of the plans and sections as relates to any tidal lands. These documents must be lodged before the 1st May.

The Board of Admiralty report to the Board of Works on the project, and the Board of Works take such report into consideration.

This clause is *not* affected by the act of 1861.

CLAUSE XLII. restricts the *compulsory* powers of purchase to land within 30 feet of the centre of a public road or quay.

CLAUSE XLIII. prevents the promoters from getting possession of any house, built wholly of stone and

lime, any yard, haggard, orchard, garden, avenue, ornamental ground, plantation, lawn, or bleach green, without the consent of the owner.

CLAUSE XLIV. gives a power to any one owning a sewer, drain, or pipe lying across the tramway, to open same for repair, without payment for unavoidable damage to tramway.

THE TRAMWAYS (*Ireland*) AMENDMENT ACT, 1861.

CLAUSE 2. abolishes the provisional approval of the Grand Jury, and enables them to approve or disapprove *definitively* at either the summer or spring assizes.

CLAUSE 3. allows application of promoters to either spring or summer assizes.

CLAUSE 4. "In case the application is made at the spring assizes, the advertisements required by the first section of the said Act, shall be published in the month of November or December, or either of them, immediately preceding; and the deposits required by the second and fourth sections of the said Act shall be made on or before the first and twelfth day of December respectively, and the notices required by the third section shall be given on or before the second day of December".

CLAUSE 5. gives power to any one entitled to appear before the Grand Jury on the inquiry, to traverse their approval, on two grounds:—

(1) That the preliminaries required by law have not been complied with.

(3) The construction of the work would not be beneficial to the public.

The first traverse is to be argued before, and decided by, a judge sitting at the time. The second traverse is to be brought before a jury. Traverses must be decided at the same assizes as the application is made at.

CLAUSE 6. requires the Board of Works to hold the inquiry, as ordered by the previous Act, before the assizes at which the application is made.

CLAUSE 7. restricts the inquiry of the Board of Works to the merits in an engineering point of view (*Vide* Clause IX. of previous Act).

CLAUSE 9. gives power to the promoters to commence work, after obtaining the Order in Council, without waiting for the Act, but only in cases where no petitions of appeal against the approval of the Grand Jury have been presented.

CLAUSE 10. gives the Grand Jury, with the previous approbation of the Presentment Sessions, power to authorize any persons constructing a tramway to cross a highway.

This clause applies to the case of a tramway in course of construction, where the promoters want additional power to cross a road. By this clause they can get power to do so, without having to go through the tedious work of a new Order in Council and an Act of Parliament.

No alteration is made in the last Act of the date of lodgment of maps, etc., with the Board of Admiralty. As it stands at present, the Act requires plans of the tramway, if affecting tidal lands, to be lodged with the Admiralty on or before the 1st of May in the year in which the application *is begun.*

Subjoined is a comparative statement of the progress of a railway bill, and a tramway application, as far as the engineer is concerned. The striking differences are marked by Italics :—

RAILWAY BILL.	TRAMWAY APPLICATIONS.*
1. Notices to be advertised in October or November.	1. Notices to be inserted in April or May. (November and December).
2. Plans and sections and published maps, are to be lodged on or before the 30th November.	2. Plans and sections and published maps, *signed by the engineer*, are to be lodged on or before the 1st day of May. (1st day of December).
3. Notice to be given to each person interested in any land	3. Notice to be given to each person interested in any land

* The dates within brackets refer to an application to the spring assizes.

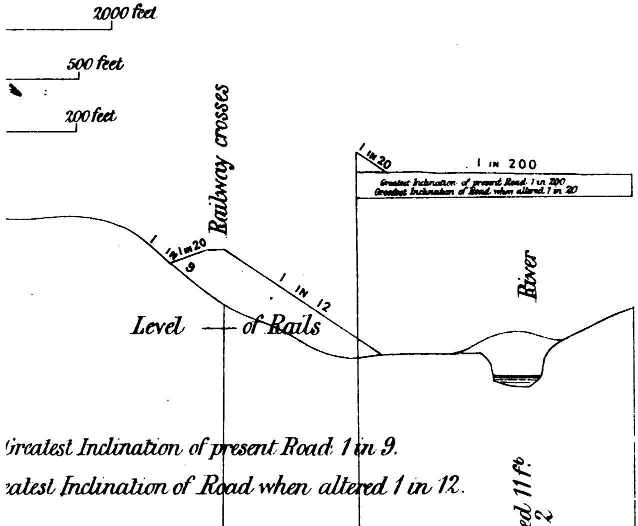
referenced, on or before the 15th day of December.

4. Estimate of expense to be lodged on or before the 31st day of December.
5. Board of Trade reports on the Bill.
6. Compliance with standing orders must be proved. Compliance or non-compliance to be decided by the Examiner.
7. If compliance with Standing Orders be proved, the Bill, if opposed, goes to a Committee of the House of Commons.*
8. If it passes this Committee, compliance with Standing Orders of the House of Lords must be proved before the second reading.
9. The Bill goes before a Committee of the House of Lords.
10. If unopposed on the third reading, it receives the royal assent, and becomes an ACT.

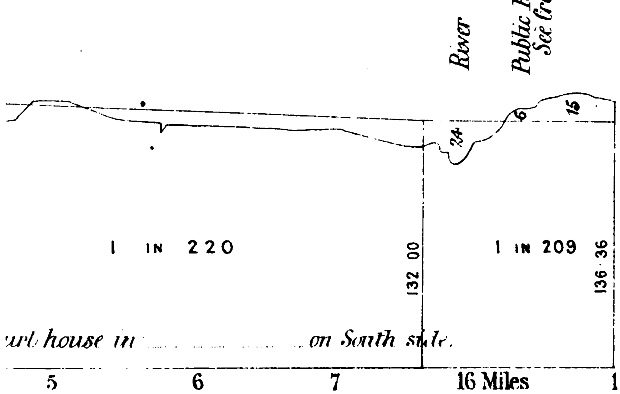
referenced, on or before the 2nd day of May. (2nd day of December).

4. Estimate to be lodged on or before the 12th day of May. (12th day of December).
5. Board of Works *holds a public inquiry, hears evidence in opposition to the merits in an engineering point of view, and reports on the application.*
6. Grand Jury inquire into the application, and may approve or disapprove of it.
7. If approved of, it may be traversed on compliance with requirements of Act, traverse to be decided by a judge.
8. If approved of, may be traversed on merits. Traverse to be decided by a jury.
9. If it succeeds in the traverses, it goes before the Lord Lieutenant in Council, who hears opposition, and if all appeals are disallowed, issues an Order in Council for the making of the tramway.
10. The Order in Council is referred to Parliament, and embodied in an ACT.

* The order of Committees may be reversed, and the Bill may come before the Lords first.



Cross Section N° 2.



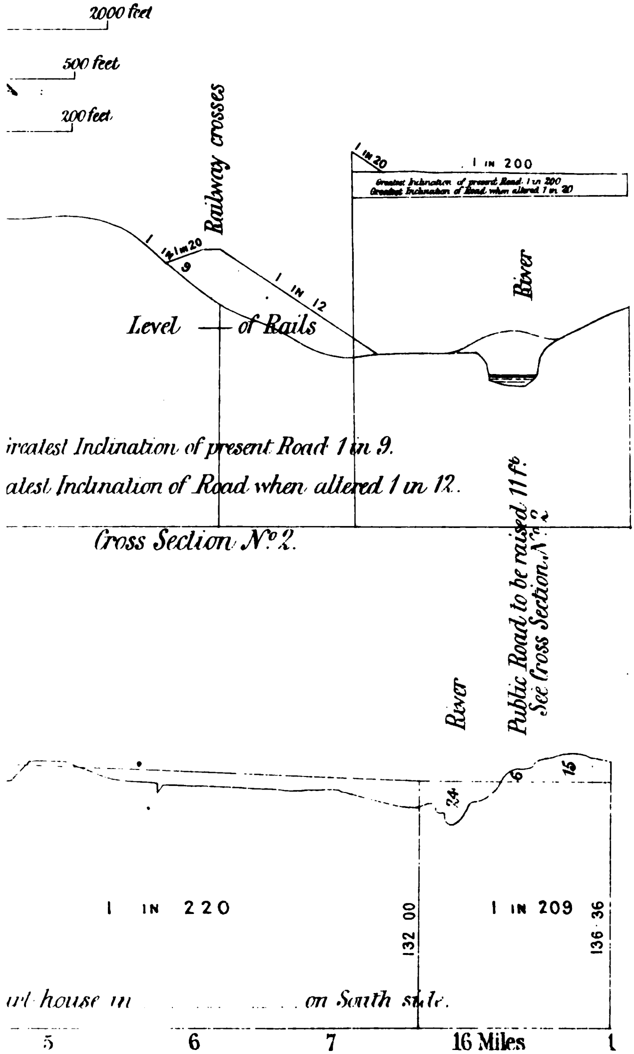
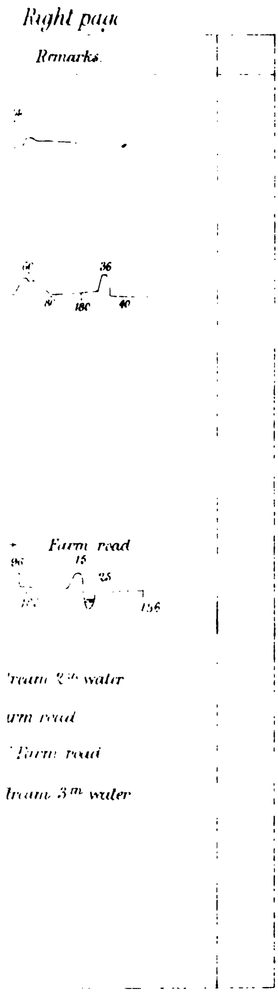

2000 feet
500 feet
200 feet
Railway crosses
1 in 20
1 in 200
Greatest Inclination of present Road 1 in 200
Greatest Inclination of Road when altered 1 in 20
9
1 in 12
Level of Rails
River
Inclination of present Road 1 in 9.
Inclination of Road when altered 1 in 12.
Cross Section No. 2.
Public Road to be raised 11 ft.
See Cross Section No. 2
River
24
6
15
1 in 220
132 00
1 in 209
136·36
house
on South side.
5
6
7
16 Miles
1

PLATE 2.


Right page
Remarks.
36
180
40
Farm road
15
25
156
ream 2nd water
arm road
Farm road
ream 3rd water